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# ELEMENTARY COURSE

OF

# BOTANY,

## STRUCTURAL, PHYSIOLOGICAL,

AND

## SYSTEMATIC.

BY

PROFESSOR ARTHUR HENFREY, F.R.S., L.S., &c.

ILLUSTRATED BY UPWARDS OF FIVE HUNDRED WOODCUTS.

*SECOND EDITION.*

REVISED, AND IN PART RE-WRITTEN,

BY MAXWELL T. MASTERS, M.D., F.R.S., L.S., &c.,

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# AUTHOR'S PREFACE.

When the author published his 'Outlines of Structural and Physiological Botany' ten years ago, it was his intention to prepare a second volume devoted to Systematic Botany. Various circumstances concurred to prevent that plan from being carried into effect, among the most important of which were, first, the rapid advance made in certain departments of Structural Botany soon after that date, which rendered a recasting of the existing volume desirable, and, secondly, the gradually strengthening conviction, derived from experience in lecturing, that the arrangement of the matter in the 'Outlines' was not that best adapted for the instruction of those for whose use it was intended.

Notwithstanding that the author's own labours have been chiefly in the field of Physiological Botany, he quite concurs with the opinion expressed by the distinguished authors of the 'Flora Indica,' who believe that disservice is done to the cause of Botany by occupying the attention of students in the first instance with the abstract parts of the science. The largest class of students of Botany are those who pursue the subject as one included in the prescribed course of medical education. One short course of Lectures is devoted to this science, and three months is commonly all the time allotted to the teacher for laying the foundations and building the superstructure of a knowledge of Botany in the minds of his pupils, very few of whom come prepared even with the most rudimentary acquaintance with the science. To direct the attention of the student to a series of isolated facts and abstract propositions relating to the elementary anatomy of plants, is to cause him to charge his memory or his note-book with materials in which he can take but little interest, from his incapacity to perceive their value or applications. Some of the most important questions of Physiology are as yet in no very advanced state, and the conflicting evidence on many of these cannot be properly appreciated without an extensive knowledge of plants.

But if we endeavour to seize the floating conceptions furnished by common experience, and to fix and define them by a course of exact practical observation of the more accessible characters of plants (showing the relations of these as they occur in different divisions of the Vegetable Kingdom), we place the student in a position which enables him to proceed at once with an inquiry into the peculiarities of the plants he meets with, and in this way to acquire a fund of practical knowledge, which is not only absolutely requisite before entering on abstract inquiries, but is especially calculated to secure his permanent interest in the study.

Physiology is undoubtedly of the highest importance, and from its nature is that part of the Science which, were it not for the above difficulties, would with most advantage be taught by Lectures. If the previous education of medical students prepared them, as it should, with an elementary knowledge of the Natural Sciences, we should make Physiology the most conspicuous feature of a course of Botany in a Medical School. In the meantime we subordinate it to the other branches in practical teaching, and in this volume have dealt with it in what we regard as its proper place in the order of study.

A compendious manual of a science makes peculiar demands upon the powers of an author. Originality of matter has little place. The exercise of judgment and conscientiousness in examination of original sources are everywhere demanded; and these are of course most beneficially employed when they rest upon an extensive basis of practical experience. Much care and labour have been expended in the preparation for, and execution of, the present volume; and the author trusts that his experience as a teacher may prove to have enabled him to produce a good working text-book for the student, from which may be obtained a groundwork of knowledge in all branches of the Science, without the attention being diverted from the more striking features of the subject by details comparatively unimportant.

ARTHUR HENFREY.

London, June 1857.

# EDITOR'S PREFACE.

THE Editor's duty in superintending the publication of this volume was clear, though its execution has proved onerous. To revise the whole work, to eliminate passages which the progress of Botanical Science had rendered obsolete, to insert new material, and to endeavour, as far as circumstances would allow, to render the book as good an exponent of the state of botany at the present time as the previous edition was at the date of its publication,—such was the course laid down to be followed. To this end Professor Henfrey's text has been left intact in all cases where this could be done without compromising its value. In particular those portions which have special interest as embodying the results of the lamented author's original researches have been carefully retained.

Little alteration and comparatively slight additions have been needed in the chapters relating to Morphology and Physiological Anatomy. The latter department especially was so thoroughly investigated by the author that it is no matter for wonder, though assuredly it is for congratulation, that modifications, relatively unimportant, were all that appeared necessary in the portion of the work devoted to this subject. Professor Henfrey in his lifetime was the almost solitary representative in this country of Physiological Anatomy. Certainly no Englishman has of late years earned in this special department so well founded a reputation, and great has been the loss to English science from his premature decease.

In other sections the changes have necessarily been greater. The systematic description of the Natural Orders has been condensed, and to some extent recast, especially as regards the Cryptogamia. In his knowledge of this latter class of plants the author was also pre-eminent; but the additions to this department of Botanical science have been so great and so important, that considerable reconstruction has been necessary to bring the work up to the present time; but here, as elsewhere, wherever it has been practicable to do so, Professor Henfrey's views have been scrupulously regarded.

It will be seen that, in the portions relating to Systematic Botany, frequent reference has been made to the views of Messrs. Bentham and Hooker on the affinities of the various families of plants. The volume of the 'Genera Plantarum' already published by those distinguished botanists, and which it is to be hoped will speedily be followed by the remainder, has served as a guide so far as its limits have allowed. In the case of the orders not included in the above-named volume, the Editor has availed himself of the 'Flora Australiensis' of Mr. Bentham, the second edition of Dr. Harvey's 'Genera of South-African Plants,' edited by Dr. Hooker, as well as of manuscript notes kindly placed at his disposal by the latter gentleman. In this manner it is hoped that a general idea of the views of those eminent botanists as regards the affinities of the larger groups of plants may be obtained.

Great progress has been made in matters pertaining to physiology, especially in Germany and France, since the publication of the original edition; and hence a corresponding amount of labour has been bestowed by the Editor on those portions of the book allotted to the consideration of those subjects.

The sections relating to geographical and geological botany are, in a student's manual, necessarily treated merely in outline; and hence they have been left nearly as written by the author, with a few requisite additions and modifications.

By means of careful condensation, redisposition of material, and different typographical arrangements, a large amount of new matter and some additional illustrations have been added, without materially increasing the size of the volume. In this, as in all other matters, the convenience of the student has been carefully considered.

M. T. M.

June 1870.

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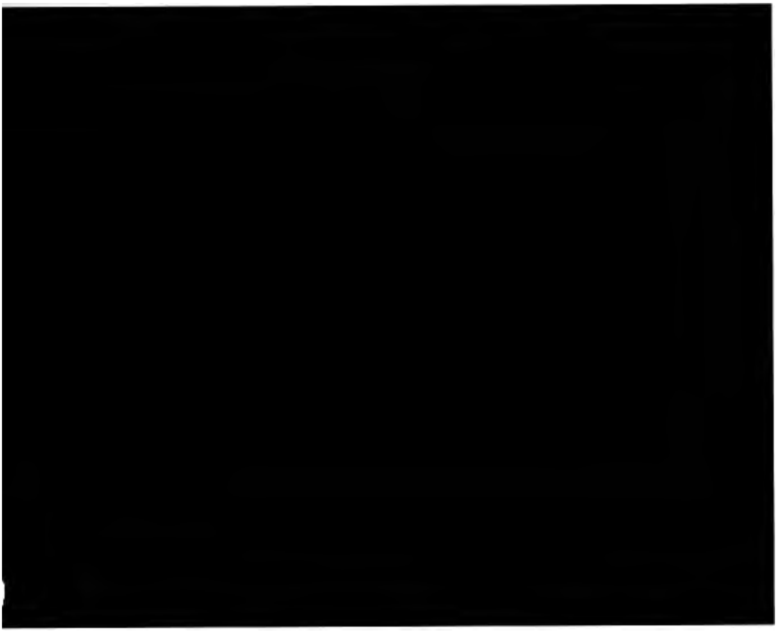
### ERRATUM.

The words "*Section* A. Ovary inferior," at p. 372, line 23 from the top, should be deleted.



AN

# ELEMENTARY COURSE

OF

# BOTANY.

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## INTRODUCTION.

### SECT. 1. OBJECTS AND SUBDIVISIONS OF THE SCIENCE.

1. BOTANY is that department of Natural Science which deals with Plants; a knowledge of it consists of an acquaintance with a body of accurately observed facts connected with the Vegetable Kingdom, and with the laws which have been deduced from them as expressions of the order and relations in which they present themselves in nature.

No attempt is here made to *define* a plant, so as to separate the abstract conception of this kind of being from that of minerals and animals; for an absolute and exact definition cannot be properly comprehended without a familiarity with a large portion of the matters which it is the object of the present treatise to teach. At the outset we must be content with the conception of a plant furnished by the previous experience of the student; this will be enlarged and at the same time rendered clearer by the study of the following pages; and after the more important principles of physiology have been expounded, something like a satisfactory definition may be attempted.

2. Botany is divisible into two principal departments:—the *Natural History of Plants*, which deals with the characteristic phenomena presented by the individual kinds of plants; and *Philosophical Botany*, the object of which is to ascertain the general facts and laws which may be recognized as pertaining to more or less considerable assemblages of plants.

Philosophical Botany represents the pure science; and it is with the departments of this we have chiefly to do in this work. The Natural History of plants, which in early times constituted the whole science, resolves itself, at the present time, into a number of distinct branches of *Applied* or *Practical Botany*.

3. Philosophical Botany includes the following departments:—

I. *Morphology*, or *Comparative Anatomy* of plants, consisting of the study of the forms of the *organs*, or physiologically diverse parts of plants.

II. *Elementary* or *Physiological Anatomy*: the study of the tissues and the intimate structure of the organs.

With these two are conveniently associated the *Terminology*, or technical language of Botany.

III. *Physiology*: the study of vital phenomena, including those specially characteristic of plants, and also those which are common to the animal kingdom, as well as the consideration of the general cosmical agents pertaining to the mineral kingdom equally with the two others.

IV. *Classification*, which is the study of the mode of placing the kinds of plants in groups and series of groups so as to express in an abstract form their mutual relations and their degrees of perfection in organization. This department includes the *Principles* of *Descriptive Botany*, and of the *Nomenclature* of kinds and classes of plants.

As all natural science is founded on experience, the exposition of the laws and generalizations belonging to the foregoing departments must necessarily be accompanied by more or less extended descriptions of matters of fact; so that much of the material belonging to the Natural History of Plants, or Applied Botany, must be included under these heads. This is especially the case in the department of *Classification*, where on minor grounds it is advisable to associate the tabular arrangement of the groups with a systematic sketch not only of the botanical characters, but of the general history of the principal Natural Orders of plants.

4. Applied Botany is divisible into many departments. That most closely connected with Philosophical Botany is *Descriptive Botany*, which is the art of describing the *species* or particular kinds of plants in technical language, in such a manner that they may be readily recognized by botanists. Special works are commonly devoted to this branch, and very commonly these confine themselves to the plants of a limited area, as a particular country or even province; such books are called *Floras*. *Pharmaceutical Botany* treats of the medicinal, nutritious, or poisonous properties of plants. Vegetables possessing such properties are generally included under the head of *Materia Medica*, to which subject special treatises are also devoted. *Agricultural*, *Horticultural*, and *Economic Botany* are often treated as distinct subjects: the first two are founded on the application of

the principles of Physiological Botany; the last on the astertained facts of Comparative and Elementary Anatomy, and on the combination of these facts with chemical and mechanical knowledge.

None of these departments of Applied Botany receive separate treatment in this work, although incidental reference is made to them to indicate the application of the laws and facts of philosophical Botany to them.

5. *Botanical Geography* and *Botanical Geology* (or *Palæontology*) are mixed studies, founded on the association of the results of pure and applied Botany with those of other sciences: the first is related most closely to Physiological Botany, but has some problems *sui generis*, to be solved only by independent facts and observations; the second has some very interesting relations with the Scientific Classification of plants. These two departments require a brief separate treatment in a text-book of Botany, as applications of the science having a peculiar philosophical interest.

6. The characters of the principal divisions of the Vegetable Kingdom being morphological as well as physiological, while those of the subordinate divisions are almost purely morphological, the study of the Physiological Anatomy and the Physiology of Plants admits of being postponed in an elementary course of study, until after a general examination of the characters of the Classes and Orders of plants has been made,—an arrangement which is found very advantageous in teaching, since it postpones the consideration of the more abstract questions until the student has made some considerable advance in a general knowledge of Botany.

In the present work, therefore, the different departments are treated of in the following order:—

Part 1. MORPHOLOGY, or COMPARATIVE ANATOMY OF PLANTS.
„ 2. SYSTEMATIC BOTANY.
„ 3. PHYSIOLOGY, including PHYSIOLOGICAL ANATOMY.
„ 4. GEOGRAPHICAL and GEOLOGICAL BOTANY.

## SECT. 2. GENERAL CHARACTER OF THE METHODS AND MEANS USED IN THE STUDY OF BOTANY.

7. The study of the morphology of plants, to which the first Part of this volume is devoted, necessitates little more than a supply of fresh plants, a penknife, and a pocket magnifying-glass of moderate power. Roots, stems, and leaves require no preparation; and the dissection of most flowers is a very simple operation. The majority of the characters of many flowers may be observed by simply removing successively the calyx, corolla, and stamens with a penknife, and by examining the pistil or pistils by perpendicular and cross

slices. Perpendicular sections of entire flowers are very instructive; and horizontal sections through unopened buds, both of leaves and flowers, are likewise necessary for the examination of the relative position of the organs, and of the vernation and æstivation. When flowers are extremely minute, and also in the investigation of the structure of ovules and seeds, the *simple microscope* becomes almost a requisite. This instrument consists essentially of a stand, provided with a moveable arm supporting a magnifying-glass over a stage upon which the object is laid, so that both hands may be at liberty for its dissection. The stage is an open frame, upon which a slip of glass rests, and the object to be examined, lying on the glass slip, may be illuminated by a small mirror beneath sending light *through* it, or by a condensing lens at the side bringing a bright spot of converging rays *upon* it. The dissection is effected with a fine dissecting scalpel and needles: the simplest dissecting-needles are made by forcing the heads of sewing-needles into the cedar sticks used for camel-hair pencils, securing them with a little sealing-wax.

8. In pursuing the study of Systematic Botany, the same means are used, the only difference being that the investigation of each flower is carried out in detail, so as to ascertain all its characters, with a view to determine its special peculiarities and its relations to other plants. It is a very useful and improving exercise for the student to make a thorough analysis, and to write down in full the characters of the plants he meets with, before searching in books for their names, and also to do the same with known plants, and then to compare the characters thus drawn up with those given in authentic works.

9. To those who follow out Systematic Botany in detail, and wish to gain acquaintance with the species of plants, it becomes necessary to have access to an *Herbarium*—that is, a collection of plants so dried that the specific characters, at least, are preserved. In many cases, if the drying has been carefully effected, the generic characters may be ascertained by soaking the flowers in hot water, when they become softened and the parts separable, like tea-leaves after infusion. Herbaria furnish materials for the comparison of plants, as it is seldom that a number of species of one genus can be obtained in a fresh state at one time. Persons living in the country, and studying the British plants, will find it indispensable to form a collection of dried specimens.

Plants are dried by laying them out smoothly when fresh between several folds of paper (either stout blotting-paper, or, still better, what is called "Botanical paper," made for the purpose), and submitting them to pressure by means of weights laid on a board. The damp paper must be frequently replaced by dry sheets, and when the plants are quite dry, they may be fixed to half-sheets of white paper, with a little thin glue, or by simply attaching them by bands of gummed paper, or by stitching. The best kind of paper is stout white cartridge, of *demy* size; some prefer a stout writing-paper, rather smaller, of the same size as lawyer's "draft"-paper. Only one species should be placed upon one half-sheet; the name should be written on the lower left-hand corner. The half-sheets containing the species of a genus may be placed in a sheet of the same paper, the name of the genus being written outside, likewise at the left-hand bottom corner. These sheets may be kept in drawers of a cabinet, or tied up in bundles, between covers of stout pasteboard. It is advisable to poison the dried plants with a solution of corrosive sublimate in spirits of wine, as some of them are very liable to be devoured, especially their flowers, by insects of various kinds. Plants preserved in herbaria, especially if rare or local species, should always have the place where they have been gathered carefully noted.

10. The study of the Elementary Anatomy and the Physiology of Plants opens up a far more extensive field for the employment of instruments and technical manipulations.

11. First of all, a *compound microscope* is an essential. For the student, magnifying-powers of 1-inch, ½-inch, and ¼-inch are amply sufficient, although the more abstruse questions require the most perfect and powerful instruments that can be obtained. For general students' use the binocular microscope has no advantage over the ordinary instrument.

The tissues of plants are observed for the most part by means of extremely thin slices passing in various directions through the structures. These are usually best made with a razor. Stems, pieces of wood, and other firm objects, when being cut, may be held in the finger and thumb of the left hand; delicate and thin structures, like leaves &c., should be placed between the two halves of a split cork, or rolled round the edge of a cork, and the cork supported by sticking it in the neck of a vial or test-tube, which serves as a handle. Seeds and similar small objects may be fixed, for slicing, on a piece of white wax. Where it is not imperative to examine the tissues *in situ*, small portions may be softened by boiling in water.

Sometimes it is useful to obtain preparations by macerating the softer tissues, either in water, or weak acids. In the case of woody structures recourse may be had to an operation which requires a little care: a fragment of the wood is to be placed in a watch-glass with a morsel of chlorate of potash, to which a drop or two of nitric acid is added by means of a glass rod, the whole being gently heated for a minute or two, and water being poured on to prevent complete solution. The fragments macerated in any of these ways being placed on a slip of glass beneath the simple microscope, the elementary organs may be picked out with a needle or extremely fine camel-hair pencil, under a simple lens of ½- or ¼-inch focus, and removed to a clean slide.

The thin slices, or the fragments of macerated tissues, should be laid upon a slip of glass, a drop of water added, and a thin glass cover laid on. They may then be examined under the compound microscope. Objects of microscopic dimensions, such as minute Algæ, Fungi, pollen-grains, &c., require no preparation.

It is very instructive to apply chemical reagents of various kinds to the objects lying in water upon the microscopic slide. Dilute sulphuric acid is often useful to coagulate protoplasmic structures, and to clear delicate tissues; when this is added first, and afterwards solution of iodine, the younger cellular structures turn blue, while the older ones become deep yellow. Iodine alone colours starch-grains blue. Sugar and nitric acid colour the protoplasmic structures red. These reagents may be applied by means of dropping from a glass rod or fine tube. It is often advantageous to soak the sections for some hours in a solution of pure carmine in ammonia diluted with water. The nuclei and cell-contents become tinged with the carmine, and can thus be more readily distinguished from the cell-wall. More particular reference will be made to them in the chapters on Anatomy. Microscopic preparations of soft vegetable structures are best preserved in glycerine or strong solution of chloride of calcium. Some objects are advantageously mounted in Canada balsam; these must be well dried first, and, for a few days previously to mounting, should be soaked in spirits of turpentine.

Those who desire to obtain minute instructions on the manipulations necessary for the study of Vegetable Anatomy, may consult Schacht's 'Microscope,' translated by Currey, or the articles on these subjects in the 'Micrographic Dictionary.'

In physiological investigation various pieces of philosophical apparatus are requisite. It will suffice to notice these when their applications are mentioned.

# PART I.

# MORPHOLOGY,

OR

# COMPARATIVE ANATOMY.

## CHAPTER I.

### GENERAL MORPHOLOGY.

12. The functions of plants being comparatively simple and, to speak in general terms, limited to those of nutrition and reproduction, the physiological classes of organs are few. The immense diversity which presents itself in the Vegetable Kingdom depends chiefly upon varieties in the form of organs performing similar functions. In addition to this, the organs of plants are displayed externally, not enclosed in cavities, or surrounded by an integument or shell like that of animals, so that the external forms of plants furnish a guide to the discrimination of their most essential distinctive characters.

Sense and voluntary motion being absent in plants, and their organic life being of a diffused character, they are without the nervous system and the organs subservient to it, and without the connected system of blood-vessels, by which, in the majority of animals, the unity and interdependence of the nutritive processes are maintained. Plants consist simply of organs of absorption, digestion, respiration, and reproduction, all composed of comparatively uniform elementary tissues, and supported by a solid framework or skeleton, which is more strikingly developed according to the number of organs associated in one community, and more diverse in its mode of construction according to the variety and complexity of the physiological kinds of organs.

13. The organs of plants are not only of few physiological kinds, but their variations in form depend on secondary modifications of a very few fundamentally diverse elements. The object of Vegetable

Morphology is to ascertain what these elements are, and to trace out the laws under which they acquire the different forms which they present in fully developed plants.

The methods of Morphology consist in the comparative study of the forms of organs throughout extensive series of plants, the study of malformations arising from arrested or excessive growth (*teratology*), and, most important of all, the study of the progressive development of plants from their embryonic forms (*organogeny*).

14. The plants most familiar to uninstructed persons belong to the highest classes of plants, and exhibit the greatest morphological complexity. This complexity arises not from the number of the organs, but from the more clearly defined limitation of the various physiological functions to the different organs, which are thus more specialized, while at the same time the organs are, anatomically speaking, more intimately combined together into a connected whole, and the reproductive powers are more individualized and concentrated at particular centres.

The foregoing may be comprehended by contrasting any ordinary Flowering plant, having distinct blossoms and seed-bearing fruit, with a Fern, where the fruit is borne upon leaves generally of the usual character, and again with a Sea-weed or a Lichen, in which there is not even any distinct separation between stem and leaf-structures, and no leaf-buds exist.

15. In Flowering plants we readily distinguish, in all stages of life beyond the very earliest, two distinct kinds of product of the growth, viz. a stem or axis, and lateral organs, of various but always definite kinds and forms, such as leaves &c., which are unfolded from the buds of this axis, and become what we may call its appendages. In Sea-weeds, Lichens, and Fungi, there is no really similar diversity of parts; the axis alone is represented, always devoid of leaf-buds, and therefore of proper appendicular organs,—the axis itself assuming most varied forms, often more or less approaching those of true leaves, but never exhibiting a distinct separation into two kinds of vegetative structure such as characterizes the higher plants. A distinctive name is given to that class of axes which exist without appendicular vegetative organs. Such products as the leaf-like expansions of Sea-weeds, the scale-like plates or crusts of Lichens, or the flocculent "spawn" of Fungi, performing at once the function of stem and root and leaf, represent what is technically termed a *thallus*. Plants characterized by the possession of this kind of vegetative structure are called Thallophyta, and are contrasted with all the higher plants exhibiting the coexistence of stem and leaf, which are called Axophyta, or Cormophyta (from *cormus*, a stem).

16. But the Axophyta are again distinguishable into two very well-marked groups, by the characters of the reproductive organs,

which, moreover, connect the lower of the two groups with the Thallophyta. The Thallophyta and the lower Axophyta (including Mosses, Ferns, and allied classes) are reproduced by *spores*, a simple kind of seed, in which no *embryo* or rudimentary plant exists at the period when it is thrown off by the parent. The higher Axophyta are reproduced by true *seeds*, which are far more highly organized bodies than spores, and which are especially characterized by the presence of an *embryo*, or rudimentary plant, which is developed within them while the seed is still contained in the parent fruit. The latter division also is characterized by the possession of flowers, while the spore-bearing Axophyta are flowerless, like the Thallophyta.

From this crossing of the characteristics, according as we select the vegetative or the reproductive organs as the marks of our divisions, it becomes a matter of choice, as it were, how we shall define our principal groups, in drawing up a systematic plan of the Vegetable Kingdom. As long as it was supposed that the lower plants were asexual, it was more philosophical to select the vegetative organs, as the most general. Now, however, that there is no doubt of the existence of distinct sexual organs throughout all plants, it is more correct to take the reproductive structures for the characterization of the higher groups, since they are of greater physiological importance than the vegetative organs.

17. In the following Table the primary groups are founded on the characters of the bodies by which plants are reproduced (seeds and spores). The complex organization of seeds enables us to use subordinate characters of the same organs for futher subdivision in the higher class; in the lower group, however, the simplicity or uniformity of the structure of spores only allows us to proceed one step in this direction, and we are forced to have recourse to characters derived from other sources. The mode of occurrence of the sexual organs affords very good characters in the higher Flowerless plants; but with regard to the Thallophyta, in the present state of our knowledge, we are compelled to resort to characters of habit, which however, mark out tolerably well the natural subdivision of these plants.

In the following Table the links placed at the sides indicate the limits of the groups known by the names of *Phanerogamia*, or Flowering Plants, and *Cryptogamia*, or Flowerless Plants, on the one hand, and of *Axophyta* (or *Cormophyta*), Plants with stems, and *Thallophyta*, or Plants without opposition of stem and leaves.

### Vegetabilia.

| | | | | | |
|---|---|---|---|---|---|
| PHANEROGAMIA. | Spermocarpia, or Phanerogamia. *(Fructification producing seeds; anthers bearing pollen.)* | Angiospermia. *(Ovules contained in ovaries.)* | Dicotyledones. *(Embryo with two leaves.)* | **(ORDINARY FLOWERING PLANTS.)** | CORMOPHYTA or AXOPHYTA. |
| | | | Monocotyledones. *(Embryo with one leaf.)* | | |
| | | Gymnospermia. *(Ovules on open carpels.)* | . . . . . . . . . . . . . . | **(CONIFERS, CYCADS, &c.)** | |
| CRYPTOGAMIA. | Sporocarpia, or Cryptogamia. *(Fructification producing spores; antheridia bearing spermatozoids.)* | Angiosporæ. *(Spores formed in fruits closed until ripe; spermatozoids ciliated spiral filaments.)* | Sporogamia. *(Sexual organs produced in the spores.)* | **(CLUB-MOSSES, &c.)** | |
| | | | Thallogamia. *(Sexual organs produced on a thalloid structure developed from the spore.)* | **(FERNS AND HORSETAILS.)** | |
| | | | Axogamia. *(Sexual organs produced on the leafy stem.)* | **(MOSSES AND LIVERWORTS.)** | |
| | | Gymnosporæ. *(Spores, or mother cells of spores, superficial, or on the walls of cavities open externally before maturity; spermatozoids imperfectly known, but never spiral.)* | Hydrophyta. *(Plants living almost totally in water.)* | **(ALGÆ.)** | THALLOPHYTA. |
| | | | Aërophyta. *(Plants living almost totally in air.)* | **(LICHENS.)** | |
| | | | Hysterophyta. *(Plants usually living upon dead or living organic matter.)* | **(FUNGI.)** | |

18. By far the greater portion of the plants useful to man belong to the Spermocarpous division; and this includes also the most conspicuous and familiar forms of vegetation. Hence it is desirable that the Flowering plants should occupy a principal place in an elementary work, and, moreover, that they should be examined in the first instance, before the student is led into the study of the more obscure and minute characters of the Cryptogamia. But the study of Cryptogamous plants is indispensable to the vegetable physiologist; while it forms an interesting department of the morphology of plants, and must receive a certain share of our attention. It will be found most convenient, however, to leave the Cryptogamia completely out of view in our preliminary examination of the morphology of the Phanerogamia, reserving even the differential characters of the two great divisions until we have completed the investigation of the positive characters of the Flowering plants.

## CHAPTER II.

## MORPHOLOGY OF THE PHANEROGAMIA.

### Sect. 1. GENERAL OBSERVATIONS.

19. In any ordinary Flowering plant we readily recognize some of the most important characters of the organization. Taking the plant as a whole, we find a *stem*, furnished below with *roots* to fix it in the ground and absorb nourishment, and clothed above with green *leaves*, which are known to be the organs of respiration and digestion. Taken together these constitute the system of *vegetative organs*, more or less complicated in their development and arrangement in different cases, and concerned in the nutrition and enlargement of the individual plant (in the familiar sense of that term). At certain seasons we find, superadded to the foregoing, a system of organs constituting the *blossom*, and consisting of the *reproductive organs*, provided for the production of *seeds*, the "eggs," as it were, of plants, from which new independent individuals may be raised.

20. The blossom, or *inflorescence*, consists of one or more *flowers*, which, as will be shown hereafter, are composed of various kinds of peculiarly modified foliar appendages, more or less blended together into compound organs. For our present purpose it will suffice to describe the general and essential characters of the parts found in true flowers.

21. The outer covering of complete flowers consists of a circle of leaf-like organs, most frequently of green colour, and often united together below to form a kind of cup; this cup or circle of leaf-like organs is called the *calyx*, and its component parts are the *sepals*. Within the calyx of complete flowers we find one or more circles of ordinarily larger, but more delicate, and generally brightly coloured leaves; these are likewise united together below in many flowers; they form collectively the *corolla*, and the individual parts are called *petals*.

Fig. 1.

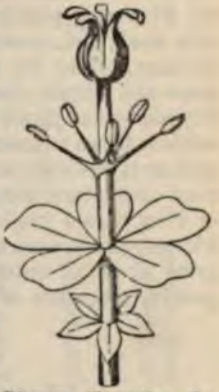


Diagram illustrating the composition of a flower, of four circles of organs, sepals, petals, stamens, and carpels.

Examples of the above may be found in the Heartsease, the Chickweed, the Primrose, &c., where there exist a green calyx and a coloured corolla. In the Tulip the outer parts of the flower consist of six similarly coloured organs, resembling ordinary petals; while in the Dock they are six greenish sepal-like organs. A close examination shows, however, that both kinds of organs stand in two circles of three, one within the other: hence many authors regard them as representing a calyx and corolla of like structure; other authors give the double circle the collective name of *perianth* or *perigone*. These irregularities will be treated of more at length hereafter.

22. The *calyx* and *corolla* have no essential share in the production of the seeds; they merely surround and protect the more important organs, either temporarily, or as entering more or less into the composition of the fruit. The collective term *floral envelopes* is therefore commonly applied to the calyx and corolla taken together; and either one or both of these may be absent in flowers which are perfectly capable of producing seeds.

23. Within the petals are placed the *stamens*, or male organs of flowers, consisting of more or less club-shaped bodies called *anthers*, usually supported upon thread-like stalks called *filaments*. The essential character of an anther is that it contains, and ultimately discharges, the fine dust-like fertilizing globules called *pollen*.

24. The centre of the flower is occupied by the *pistil* or *pistils*, the female or seed-bearing parts of the flower. Pistils are formed of foliar organs corresponding to sepals, petals, and stamens, and called *carpels*; but these are not always so readily distinguishable, on account of their varying number and degree of union, consequent upon their being crowded at the apex of the flower-stalk. The distinguishing character of a carpel is that it bears *ovules* or rudimentary seeds.

25. As the stamens furnish the pollen by which the ovules are

rendered fertile, the two sets of organs, stamens and carpels, are considered as *essential organs* of flowers, without which the purpose of the whole structure could not be performed.

In some flowers, such as those of the Hydrangea and the Snowball-bush (*Viburnum Opulus*), there is a tendency in cultivation to the abortion of the stamens and pistils; so that the flowers become *neuter*, or totally barren. But in many plants it is the natural condition for the stamens to occur in distinct flowers from the pistils, so that the individual flowers are imperfect, male or female; we have examples of this in the plants of the Cucumber family, and also in most of our native forest-trees, such as the Oak, Beech, Hazel, Poplar, &c., where the staminate and pistillate flowers are collected in separate bunches or catkins, of which the staminate fall off soon after the pollen has been discharged.

26. The *carpels*, the essential organs of a female flower, present themselves in two conditions in Flowering or Seed-bearing plants; and these two conditions form the basis for the primary subdivision of this group.

27. In by far the majority of flowers the carpels are folded up so as to form hollow cases, in the interior of which the ovules are enclosed. In such instances the pistil is divisible into regions, of which the lower hollow portion, called the *ovary*, is the most important; very frequently a stalk-like process, the *style*, is prolonged upward from its summit, terminating above in a more or less thickened head, called the *stigma*, which marks the position of an orifice leading down through the tubular style into the cavity of the ovary. In many cases the *stigma* is seated immediately upon the top of the ovary, without an intervening style (Poppy, Tulip). Plants bearing their ovules in such closed ovaries are called *Angiospermous*, or covered-seeded.

28. In Pines, Firs, the Yew, Juniper, and in the exotic family of the Cycads, the sexual organs occur in distinct flowers; and these flowers are not only devoid of proper floral envelopes, but reduced respectively to single stamens and single carpels, mostly collected into male and female *cones*. The anthers of the male cones produce *pollen*, and the carpels of the female cones produce *ovules*; but the carpels occur in the form of open scales, and the ovules are borne, naked, upon the surface or the free margins of the carpels, so that the pollen reaches them at once, without passing through a stigma and style. Plants with flowers of this kind, with which are associated many peculiarities in the mode of development of the embryos, are called *Gymnospermous*, or naked-seeded.

Much difference of opinion still exists among botanists as to the true nature of the female flower in Gymnosperms; but for the present the above explanation will suffice for the student.

29. The *Angiospermia*, comprehending the great body of the

Flowering plants, are separable into two very natural groups, which are plainly distinct in the mass, although many complex relations exist between them. Distinctive characters of the two divisions may be found in many parts of the organization of the majority of the plants; but the most general difference is that which occurs in the structure of the *embryo* contained within the seed.

30. In one division we find that the seeds, with few exceptions, contain an *embryo* in which we may distinguish *two* rudimentary leaves, or *cotyledons,* applied face to face, and having the terminal bud, or growing-point of the stem, enclosed between them. In the other division the embryo presents but *one cotyledon,* or seed-leaf, more or less rolled round the bud, like a sheath. The plants of the first division are called *Dicotyledonous,* those of the second *Monocotyledonous.*

The character of Dicotyledonous seeds may be readily examined by soaking in hot water a common Bean, a Turnip-seed, and an Almond, and by stripping off the skins, the embryo forming in these cases the entire seed. The character of Monocotyledonous seeds may be seen by cutting in half (longitudinally) an Oat, wherein the embryo may be seen to lie at one side of the base of the seed, the great mass of which consists of mealy *endosperm*; or the little cylindrical embryo of the Cocoa-nut may be found imbedded in the edible substance opposite to one of the three large black spots at one end of the shell. The structure is still more distinct, from the absence of *endosperm,* in certain water-plants, such as *Potamogeton, Alisma,* and others. The character founded upon the embryos is not absolutely distinctive of these divisions, since in some cases we have embryos without distinct cotyledons, as in the Orobanchaceæ among Dicotyledons, and in the Orchidaceæ among Monocotyledons; but the remaining characters of the respective divisions are well marked in these cases, and the exceptions are fewer in this respect than in any other that can be selected.

31. Dicotyledons and Monocotyledons are naturally divided from each other by the general characters of their mode of germination, the structure of their stems, the arrangement of the skeletons of their leaves, and the number of organs in the circles of the flowers. These distinctive characters may be made clear by contrasting them in a Table:—

| | DICOTYLEDONS. | MONOCOTYLEDONS. |
|---|---|---|
| *Germination.*— | The radicle or root-end of the embryo is developed into a tap-root. (Exorrhizæ.) | The radicle never developed; the roots lateral, pushed out through the base of the cotyledon. (Endorrhizæ.) |
| *Stems.*— | The bundles of woody substance collected into a closed circle round a central pith, and | The bundles of woody substance always remaining isolated, and ceasing to grow |

| | |
|---|---|
| retaining vitality on the outer side, by which they produce a new layer of wood every season of growth. (Exogens.) | at the fall of the leaf with which they are connected. (Endogens, so called from a mistaken view of their structure.) |
| *Leaves.*—The skeleton of the leaves formed of repeatedly branched and reticulately anastomosed fibres (*net-ribbed*). | The skeleton of the leaves formed of a number of equal, simple, and nearly independent fibres, connected only by slender cross fibres (*parallel-ribbed*). |
| *Flowers.*—Sepals, petals, and stamens, and more rarely carpels, generally five or some multiple of five. | Sepals, petals, stamens, and carpels, generally three or some multiple of three. |

It may be said that the importance of the above characters is about in the order in which they stand in the above Table; but the character derived from the leaves is far more general in the Dicotyledons than it is in the Monocotyledons, while the reverse is the case in regard to the character of the flowers, which is very constant in the Monocotyledons, while the number four, and even three, is far from rare in the Dicotyledons.

32. The ripe seed of the Gymnospermia is very much like that of Dicotyledons; but the leaves of the embryo are either more numerous, or, if but two are present, they are slit into lobes, whence these plants have been called Polycotyledonous.

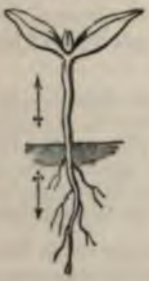
33. The germination of the seed of all the Spermocarpia or Flowering plants consists in the emergence of the *embryo*, more or less completely, from the seed, and in the unfolding of its rudimentary vegetative organs, the *radicle*, the *cotyledonary leaf* or *leaves*, with the *stem* connecting them, and which terminates above in a little bud called the *plumule*; the subsequent unfolding of the plumule gives birth to the first true leaves. Here, then, we have represented all the kinds of organs of vegetation which will form the first objects of our investigation, namely the *root*, the *stem*, and the *leaf*, together with the *buds*, or compounds of rudimentary stem and leaves, which occur at all growing-points of the plants possessing these organs (Axophyta) (fig. 2).

The phænomena of germination may be conveniently observed by sowing some Turnip-seeds and Oats in a saucer of moist sand covered by a bell-glass.

## Sect. 2. The Root.

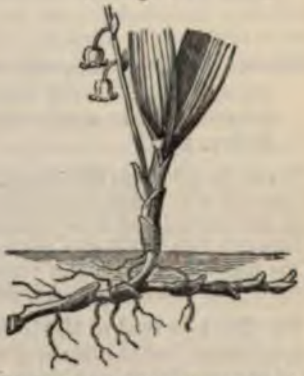
34. The root may be described in general terms as the descending leafless portion of the axis, or the prolongation downward of that central body the opposite extremity of which is directed upwards and bears the leaves and reproductive organs (fig. 2). Another character of general although not of universal application is, that it is the part of the plant which penetrates into the soil, and which serves at once as the principal organ of attachment and of nutrition.

Fig. 2.



A seedling Dicotyledonous plant, with an ascending and a descending axis.

Fig. 3.



Lily of the Valley (*Convallaria majalis*), with a subterraneous creeping stem and adventitious roots.

The statement that roots descend, is subject to slight formal exceptions in the cases of the lateral ramifications of roots, and of the lateral roots formed by parasitical and by certain climbing plants, which often retain their original direction, making a more or less obtuse angle with the stem from which they rise. These trifling exceptions are far less noticeable than the deviation of the stem from its general character as the ascending part of the axis, since in a large number of perennial plants the direction of the main stem is constantly horizontal; stems of this kind are of frequent occurrence among perennial herbaceous plants, and are ordinarily termed by gardeners "creeping roots;" for example, those of the Lily of the Valley (fig. 3), Garden Flag, Couch Grass, &c.

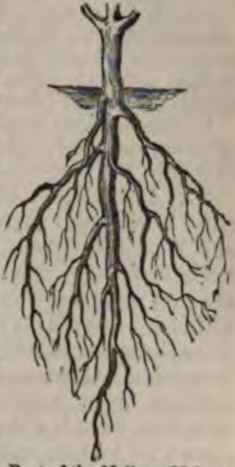
35. The true root exists in a rudimentary form (as the *radicle*) in an early stage of the existence of all plants forming stems; but the original radicle, the real inferior extremity of the axis, is only developed into an actual root in the Dicotyledons; in the Monocotyledons, and in the stem-forming Flowerless plants (such as the Ferns), the radicle is abortive, and the efficient roots are really lateral organs, comparable, in a certain way, to the leaves upon the ascending part of the stem. Where the primary radicle is deve-

loped, we have a true or *axial* root (fig. 4); but the roots which are produced from the *sides* of stems are termed *adventitious* roots (fig. 3).

The axial root may be seen well in any seedling Dicotyledonous plant, as in a young Bean or Turnip; and by watching the germination of a few seeds of such plants, the development of the radicle into the axial root may be readily traced. The axial nature of the root is clearly evident in the full-grown plants of most annual garden species of Dicotyledons; and in shrubby and arborescent perennials of this class the axial root is persistent, growing by annual increase into a large woody mass, proportionate to that of the ascending stem or trunk.

The origin of *adventitious* roots may be observed in germinating seeds of Monocotyledonous plants, such as grains of Oats, Wheat, &c.; but their essential character may be still more clearly distinguished in plants which form adventitious roots on well-developed stems and bud-like structures. The fibrils which sprout from the joints of the stems of numerous creeping plants (Ground-Ivy, Mint, Sand-Sedge, &c.), the clamping roots of Ivy-stems, the roots of an Onion-bulb, &c. afford familiar examples of adventitious roots.

Fig. 4.



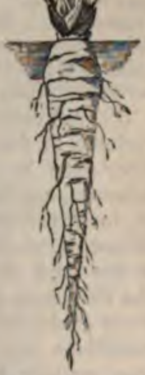
Root of the Mallow (*Malva rotundifolia*).

36. *Axial roots* branch, apparently by a kind of bifurcation of the growing point or points, and they vary to a certain extent in the relative development of their parts. Where the branches are comparatively small and the central axis is both thick and considerably elongated, the root is called a *tap-root* (fig. 5); where the branches are developed so that the principal axis is lost as it were in its own ramifications, the root is called *fibrous* (fig. 4).

The branches of the root are, in the first instance, regularly arranged in rows one above another. The number of rows varies in different cases; and the regularity of disposition is soon lost.

When the tap-root exists in herbaceous plants, it often exhibits a more or less succulent character, and becomes a *tuberous tap-root*, as in the biennial Turnip, Carrot, Beet, &c., where this organ is peculiarly developed in the first season of growth, to serve as a reservoir of nutriment. The tendency of such plants to exhibit this character in excess under the influence of stimuli, renders them extremely valuable for economic purposes. The fibrous rootlets upon the surface of tuberous tap-roots, like the Carrot, Parsnip, &c., appear to be

Fig. 5.

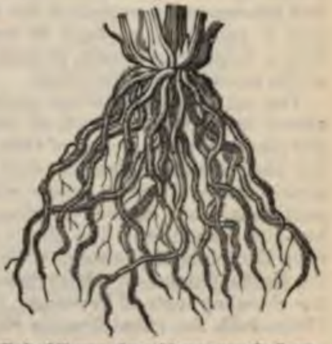


Fusiform Tap-root of the Carrot (*Daucus Carota*).

mostly true branches. A distinction is made in describing tuberous roots, between those which are *fusiform*, as in the Carrot, and those which are *napiform*, as in the Turnip. A woody tap-root is found in many forest trees, as, for example, in the Oak; but here the branches share more extensively in the increase of size, and their direction tends more to the horizontal. Fibrous roots are particularly characteristic of plants growing in light and sandy soils; the perennial, woody forms are especially characteristic of shrubby Dicotyledons.

In general terms it may be stated that the form assumed by the roots, whether true or adventitious, is in direct relation to the medium in which they grow and the purposes they have to serve.

Fig. 6.

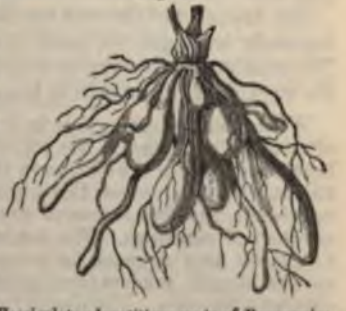


Tuft of fibrous adventitious roots of a Grass.

37. *Adventitious roots* (fig. 6) alone occur upon Monocotyledons and Flowerless plants, since their radicles are never developed; they are also necessarily the only kind which can occur upon specimens of Dicotyledonous plants which have been raised, not from seeds, but from cuttings, layers, tubers, &c. They arise from the *side* of the stem which gives birth to them, and most readily in the vicinity of buds or leaves.

They take their origin from the cambium-region, lying beneath the epidermis, rind, or bark of the stem, and break their way out through this, raising up a more or less evident and persistent rim, termed the "coleorhiza" or root-sheath; and when they decay, they leave a scar in the form of an orifice at the point where they emerged. These scars are obliterated by bark-structure in woody Dicotyledons; but in creeping rhizomes, bulbs, &c. they are persistent. Adventitious roots of Dicotyledons appear to branch in the manner of axial roots; but the branches of the adventitious roots of Monocotyledons are adventitious, and exhibit a coleorhiza.

Fig. 7.



Fasciculate adventitious roots of *Ranunculus Ficaria*, partly fibrous, partly tuberous.

38. Adventitious roots are very variable in form and consistence. They may be fibrous (fig. 6), or tuberous, and are not uncommonly of intermediate character in the Monocotyledons, consisting of more or less thick fleshy fibres. Either the fibrous or tuberous form may occur exclusively in groups of adventitious roots, or such groups may contain roots or rootlets of both kinds. In arborescent Monocotyledons the adventitious roots acquire a woody character and great

size; in herbaceous Monocotyledons they are commonly annual, or, if *tuberous*, biennial.

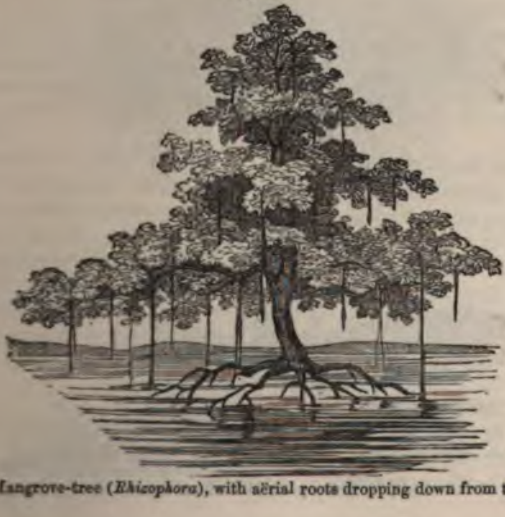
The *fibrous* adventitious roots of Monocotyledons are generally soft, much elongated, and little divided, like those at the base of bulbs of the Hyacinth, Onion, &c. (fig. 16). A mixture of fibrous and tuberous adventitious roots, forming what is called a *fasciculate* root, occurs in *Hemerocallis*, and in *Ranunculus Ficaria* (fig. 7). A peculiar modification of this structure is found also in most terrestrial Orchids. In *Spiræa Filipendula* the fibrous roots exhibit tuberous thickenings at intervals.

39. The youngest parts of rootlets, whether branches of axial roots or adventitious roots, often exhibit a coat of delicate cottony hairs, or *fibrillæ*, which are thread-like growths from the epidermis, and are thrown off in perennial roots when the epidermis gives place to the rind.

These *fibrils* must be distinguished from the ultimate ramifications of the root itself, which are sometimes very fine. Their nature will be explained under the head of the Anatomy of Roots. Examples may be found in potted Geraniums (*Pelargonium*), Heaths, &c., or in the roots of many Monocotyledonous bulbous plants and Grasses growing on light soils.

40. Roots of ordinary plants bury themselves in the soil; those of water-plants, usually more succulent in their texture, penetrate the mud, as in the Water-lilies, or hang freely down in the water, as in Duckweed and the Water Crowfoot. A number of plants exhibit what are called *aërial* roots, which are always adventitious; and these may be either the sole radical organs of the plant, or roots developed high above the ground but growing down to reach the soil, or they may

Fig. 8.

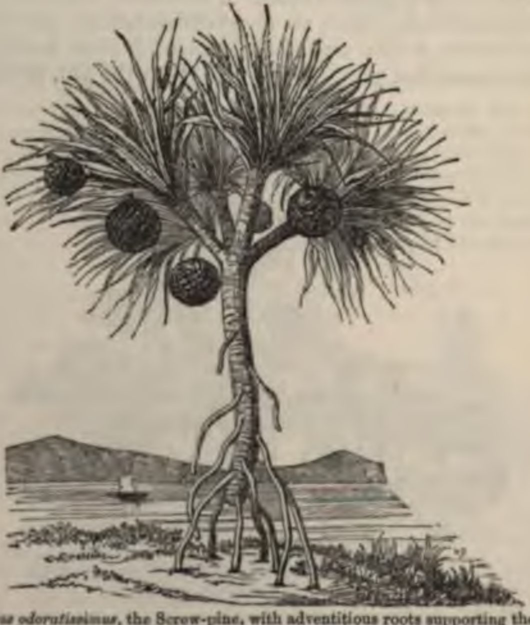


Sketch of a Mangrove-tree (*Rhizophora*), with aërial roots dropping down from the branches.

be converted into organs of support for a weak stem. In true parasitical plants the roots, more or less developed, attach themselves to, and become organically blended with the roots or stems of other plants.

The plants called *epiphytes*, such as the aërial Orchids, various Araceous plants, and members of the Pine-apple family, are possessed of aërial roots alone. The stem of such plants rests upon some foreign body, such as the branch of a tree, totally unconnected with the earth, and produces long adventitious roots which hang suspended in the atmosphere, from which they absorb their food in the state of vapour. Roots developed in the air, and subsequently descending, present themselves in various conditions. One of the most remarkable is that which is observed in the Mangroves (fig. 8) (Rhizophoraceæ), where the seed germinates in the fruit while the latter is still attached to the tree, and drops down its long radicle until it reaches the mud in which these trees grow, so that the stem of the young plant is enabled to establish itself firmly in the uncertain soil before it detaches itself from the parent. This is an axial root. In the Banyan tree (*Ficus indica*) adventitious roots are frequently developed on the branches, which, descending to the earth, penetrate into it and become supporting columns, which ultimately assume the appearance of trunks, and give the tree the appearance of a group or even a grove of trees united together at their heads. The roots of the arborescent Mono-

Fig. 9.



*Pandanus odoratissimus*, the Screw-pine, with adventitious roots supporting the trunk.

cotyledons partake to a certain extent of the same character; and those of Palm-trees are observed to arise successively one above another in a spiral course near the base of the stem, growing outwards and downwards to penetrate the ground, the older ones ultimately decaying. In the Screw-pines (*Pandanus*), plants growing on the shores of the Indian Islands (fig. 9), this is still more striking and distinct, as the spiral line which they form is more open, and the roots arise for a long way up the stem; here also the older roots and the base of the stem decay, so that the whole plant comes to be supported by the lateral adventitious roots, as on so many props. Aërial roots becoming organs of attachment may be seen in the climbing stems of Ivy, of the garden Bignonia (*Tecoma radicans*), &c.

Parasitic plants developed from seeds present, in their earliest stages, a radicle which in some cases becomes developed, in others not, or only in a peculiar manner. Some germinate in the usual way, in the earth, and their roots seek out those of their proper nurse-plants, to which they attach themselves organically, either superficially or by penetrating deeply into the interior; in such cases they may be wholly parasitic, as in the leafless Broom-rapes (*Orobanchaceæ*), or only partly dependent, as in *Thesium*, *Rhinanthus*, and *Melampyrum*. Others germinate in the usual way in the soil; but their young stems attach themselves to those of other plants by adventitious roots developed at the points of contact, while the lower part of the parasite, connected with the ground, soon dies away, as in the Dodder (*Cuscuta*). The woody parasites, Mistletoe (*Viscum*), *Myzodendron*, and others, are developed from seed upon the spot where they are attached. In the Mistletoe, the seed clings by its viscid pulp; in *Myzodendron* by coiled hairy arms; and when the radicle sprouts, it drives its way through the rind of the nurse plant until it reaches the cambium layer, where it connects itself organically, becoming grafted exactly like a budded rose. No further development of root-structure occurring here, the full-grown plant appears rootless, and like a branch or graft upon the nurse tree. The earlier stages of growth of the Rhizantheæ, root-parasites composed chiefly of inflorescence, are not known; probably they are analogous to those of *Viscum* in the first instance, but with the addition of horizontal growths of stem-structure beneath the bark of the nurse-plant.

41. Roots, as a general rule, are destitute of leaf-buds, which fact serves to distinguish them from *rhizomes* or *root-stocks* (STEMS). But under certain circumstances, roots, as indeed every part of the vegetable structure, may be made to form buds, but always from the sides, never from the end as in stems. Some trees are especially prone to this, and may be propagated by cuttings of the root, such as *Pyrus japonica*, *Maclura aurantiaca*, the Plum-tree, &c. The root of the *Anemone japonica* likewise produces buds very readily.

## Sect. 3. THE STEM.

42. The stem is the ascending portion of the axis of a plant (fig. 2). It is characterized by its growth taking place in a direction contrary to that of the roots, and by bearing on its sides regu-

larly arranged leaves or modifications of leaves, forming the *lateral* or *appendicular organs.*

An exception to the ascending growth occurs in the case of creeping stems, where the main axis takes a more or less horizontal position; but the first shoots of such plants, developed from their seeds, ascend, and the secondary axes, which bear the efficient leaves, assume the erect position, as is seen in the tufted habit of growth of plants with a subterraneous main stem.

43. Every stem is developed from a bud, which consists of a conical rudiment of the stem bearing rudimentary leaves crowded upon its sides. The primary bud of the stem of Flowering plants presents itself as the *plumule* (fig. 2) of the embryo; and so long as this axis continues to grow, a bud (the *terminal bud*) is found at its extremity. The branching of a stem depends upon the development of lateral buds, which as a general rule appear only in the *axil* or upper angle between the base of a leaf and the stem, whence they are called *axillary buds.*

There is in many embryo plants a small portion of the axis intermediate in structure as in position between the true root and the true stem (fig. 2). This "*hypocotyledonary axis*" often gives off shoots, by which it may be distinguished from roots; moreover it is either cylindrical or tapers upwards, while a root tapers in the opposite direction. This hypocotyledonary axis forms the trunk of the extraordinary plant called *Welwitschia*, hereafter described.

44. The place whence a leaf arises marks the position of a structural region endowed with special physiological activity; it defines externally a point where the internal tissues have a peculiar arrangement. Hence a particular name is applied to it, that of *node*; sometimes a kind of articulation of the stem occurs at this point, but not as a general rule. The intervals between the points of origin of leaves are called the *internodes.* In buds, the internodes are not yet developed. In a large majority of ascending stems, the internodes become considerably developed, so that the leaves ultimately appear stationed at distinct intervals. In many subterranean stems, at the lower part of the stems of many herbaceous plants (fig. 10), and in the trunks of many

Fig. 10.

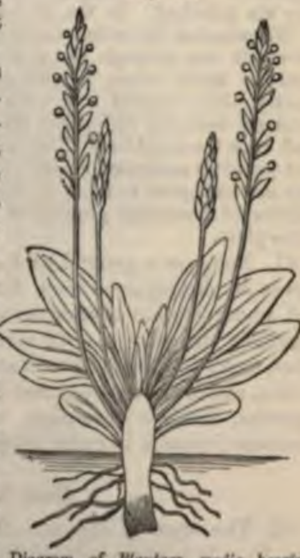


Diagram of *Plantago media* bearing leaves crowded on a stem with undeveloped internodes.

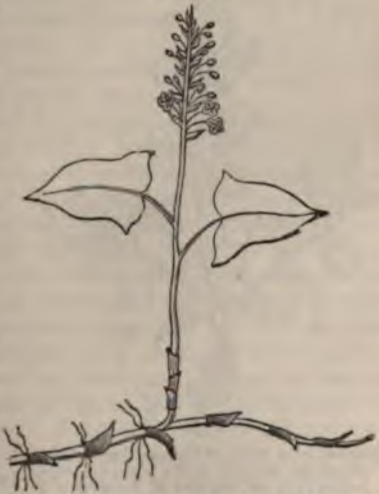
of the arborescent Monocotyledons, the internodes never become much lengthened, and the leaves in consequence appear closely packed and more or less overlapping in the full-grown plants.

The relative development of the internodes is next in importance to the order of arrangement of the axillary buds, in affecting the general forms of stems. A clear idea of the conditions may be obtained by examining, in the first instance, what occurs in the unfolding of the bud of such a tree as the Horse-chestnut. In the bud the enveloping scales, the rudimentary leaves, and even the blossom may be distinguished, crowded on the undeveloped axis. As the leaves emerge and expand, they become separated from each other by the elongation of the internodes of the stem, until at length they stand at considerable distances along the sides of a shoot several feet long. This may be illustrated by comparing it to the separation of the joints of a telescope, when its lengths of tubes are successively pulled out. Examples of permanently undeveloped internodes are seen in the rosette-like offshoots of Houseleeks and of many other herbaceous perennials—in the first season's growth of such plants as the Turnip, Carrot, Canterbury-bell, and indeed of most biennials, where the leaves all appear to arise from the root—in the bulbs of many Monocotyledons, such as the Crocus, Hyacinth (fig. 16), &c. In these cases the flowering axis which subsequently appears often developes its internodes considerably, and rises as a tall stem. An intermediate condition is met with in stems which are elongated, but have the leaves closely overlapping, as in the common Stone-crop, many Coniferous trees, many Palms (fig. 27), &c.; and a similar condition exists in the subterraneous root-stocks of various plants, where the imperfect sheathing leaf-scales succeed each other at short intervals.

45. In the embryo of a Flowering plant it is scarcely possible to define the limits even of the stem itself, which loses itself above in the plumule, and below in the radicle. But in fully-developed stems, a general division into three regions may be distinguished, according to the kind of lateral organs which they bear, viz.:

1. The *Leaf-scale* region (fig. 11), which is mostly subterranean in its habit, and presents itself with more or less of the external appearance of a root, of an enlarged fleshy bud,

Fig. 11.



A plant of *Smilacina bifolia* with a creeping rhizome bearing *leaf-scales*, an erect *leafy* stem, and an inflorescence with *bracts*.

or of a combination of these two. The leaves upon this are never green, but are of fleshy or membranous texture and simple forms.

2. The *Leaf* region, forming the ascending stem of plants generally, especially characterized by the green colour and great development of the foliage.

3. The *Bract* region, which is also known as the *Inflorescence*, is distinguished by its smaller, more delicate, and sometimes coloured leaves, the axillary buds of which produce blossoms.

The extent, both positive and relative, in which these regions are represented is different in almost every plant; but a few general statements may be made serving to illustrate the subject. The leaf-scale region is developed chiefly in herbaceous perennial plants; and the principal modifications of it will be examined below under the heads of Rhizomes, Bulbs, and allied structures. It may be observed that the leaf-scales or abortive foliaceous organs are almost exclusively composed of the stalks or sheaths of leaves, without any part corresponding to the blade; exceptions to this, illustrating the rule, occur in tunicated bulbs like the Hyacinth (fig. 16), where the inner scales bear a green blade standing out free at the top of the bulb, and again in various subaquatic Grasses with creeping stems, in which the lower parts of the annual shoots often exhibit large open sheaths with small rudiments of blade at their summits. The region bearing perfect leaves forms the principal part of the axis in arborescent plants, where the leaf-scale region occurs only at the points where the protecting scales of the autumn buds are produced; the scars of the

Fig. 12.

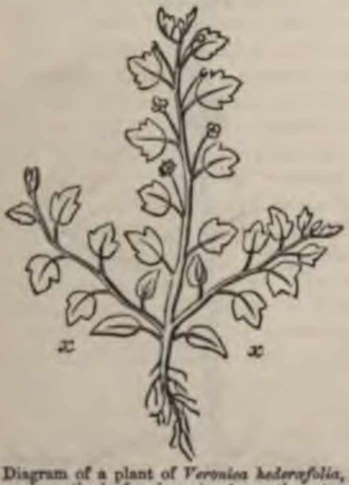


Diagram of a plant of *Veronica hederæfolia*, where the leaf-scale region bears the cotyledons *x*, *x*, and the rest of the stem is a true-leaf stem with flowers in the axils of its leaves.

Fig. 13.

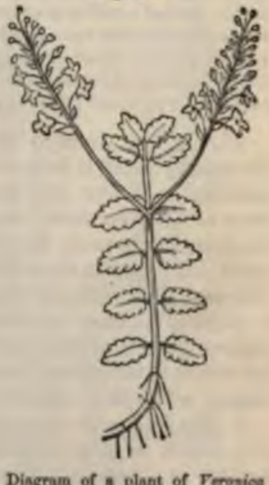


Diagram of a plant of *Veronica Chamædrys*. The lower part is a true-leaf stem, and its branches are bract-stems or inflorescences.

leaf-scales, crowded together from the non-development of the internodes are very visible at the base of the yearly shoots of many trees, for example, of the Horse-chestnut: other trees reproduce, as it were, their cotyledons at these points; the Jasmine, for example, exhibits a pair of broad undivided leaves near the base of each annual shoot. In annual plants the leaf-region is predominant, but the bract-region is relatively more developed than in trees; and the same holds good of perennial herbaceous plants. In arborescent plants the bract-region usually does not present itself until the leaf-regions of many years have been formed, and even then it is generally formed from branches of the axis which have a subordinate share in giving the special form to the entire plant; sometimes, however, the form of the ramification is much affected by the position of this region, as in the Horse-chestnut, Lilac, and other trees, where the terminal buds of shoots are developed into an inflorescence, which of course puts a stop to the onward growth at these points.

Fig. 14.

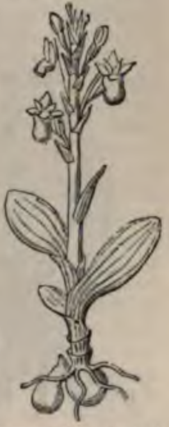


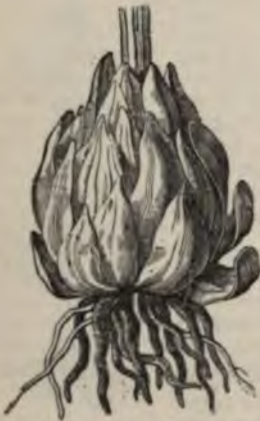
Diagram of a plant of *Ophrys arachnites.* The leaf-scale, true-leaf and bract regions successively presented in the same axis.

46. The *Leaf-scaled* stem, found especially among herbaceous perennial plants, is seldom continuous with an axial root; on the other hand, it is very prone to produce adventitious roots, as is natural to its usually subterraneous or creeping mode of growth. When its internodes are regularly although slightly developed year after year, it forms an abbreviated stem, horizontal or ascending, either below or above ground. If the main axis persists, producing a few branches each year, and as it grows at one end slowly dies away at the other, a more or less root-like structure is produced, termed a *root-stock* or *rhizome* (figs. 11 & 22). If the growth of each axis decays away at regular intervals, so as to isolate the products of the succeeding axes, the result is different, and, instead of a branching rhizome, the axis resolves itself into a number of detached portions, in the form of *corms*. If these detached portions are chiefly composed of leaf-scales, with the undeveloped stem small, so that they represent enlarged buds, they are called *bulbs* (figs. 15 & 16). Another reproductive structure belonging to the leaf-scale region of the stem is the *tuber* (fig. 19), which consists of a fleshy thickened subterraneous axis, arising in the axil of a leaf-scale, having its own internodes considerably developed, so that its leaf-scales are scattered, and cover isolated buds or "eyes." Tubers of analogous character are sometimes formed from aërial branches, as in many epiphytic Orchids, where they have a green colour and are known as *pseudo-bulbs*.

47. The *Bulb* (fig. 15) is a stem remaining permanently in the condition of a bud. Its axis consists of a disk or shortly conical

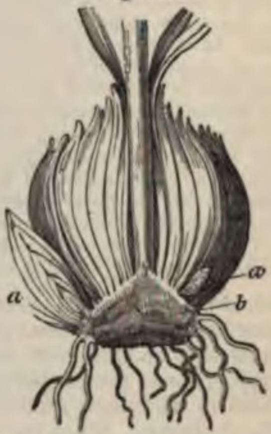
plate, from the upper surface of which arise leaf-scales of fleshy character more or less overlapping each other, and enclosing the points of growth, while one or more circles of adventitious roots are given off from the base (fig. 16). Bulbs are named, according to the character of their leaf-scales, *scaly* or *squamose* when these only partially overlap (Lily), and *tunicated* (Onion, Hyacinth), when the scales form complete sheaths. Bulbs produce flowering axes either from the terminal or from axillary buds. They are multiplied by buds developed in the axils of the scales in the form of new bulbs (*cloves*, fig. 16 *a, a*), which sooner or later become detached. When a bulb flowers from its terminal bud in its first season of growth, it is *annual*; when it only strengthens itself by forming scales in the first season, and flowers from the terminal bud in the second, it is *biennial*; when it flowers from an axillary bud, the terminal bud may be developed in the same form indefinitely and form a *perennial* bulb.

Fig. 15.



Sealy bulb of *Lilium candidum*, with adventitious roots.

Fig. 16.



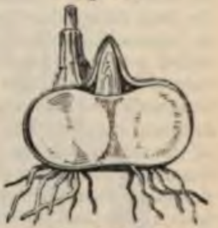
Tunicated bulb of the Garden Hyacinth, cut through perpendicularly, showing the leaf-scales arising from the abbreviated stem (*b*), and the young bulbils or cloves (*a, a*) formed in the axils of leaf-scales.

The number of leaf-scales constituting the mass of a bulb varies much in different plants: in *Gagea*, *Allium vineale*, and others there exists only one; *Allium oleraceum* has but two; the Garden Tulip and Crown Imperial have comparatively few scales, while the Lilies and the Hyacinth (figs. 15 & 16) have numerous coats or scales. A little explanation is requisite as to the terms *annual* &c. as applied to bulbs. We have an example of what is called an annual bulb in the Garden Tulip. As planted in autumn, it is a bud composed of four or five scales enveloping a central rudimentary flowering stem which terminates the main axis. In the axil of the outer scale there is an axillary bud. As the flowering stem is developed the old bulb shrinks, while the axillary bud becomes more and more perfect; so that, after the flowering season is over, it forms a new bulb, to the side of which the withered remains of the old one are attached. The terminal point of the new bud repeats the flowering, and its outer scale (sometimes the next also) subtends an axillary bud destined to become a new bulb in the next season. Such bulbs are sometimes called *præventitious,* since the bulbous structure of any given axis is formed before the true leaves and flower. The Crown Imperial (*Fritillaria imperialis*) affords an example of a *biennial* bulb. Examined in the autumn, it is found to consist of fleshy scales produced at the lower part of the axis which has just flowered; while a bud seated in the axil of the innermost of these scales is already developed, and by the decay of the old flowering stem has come to occupy the centre of the bulb. In the next season this bud flowers: at first it is surrounded by the scales of its parent axis; but after the flowering is over, these very quickly shrivel up and disappear, the axis which has just flowered giving origin at its base to a number of scales replacing them; and while the flowering stem decays away down to these scales, a new axillary bud is developed in the axil of its innermost or uppermost basal scale. Thus the bulb always bears growths belonging to two seasons on the same axis: the nutrient leaf-scales of each axis are developed upon it *after* it has flowered, and serve for the support of the flower of the next axis. Such bulbs are sometimes called *postventitious*, and may be termed *definite* to distinguish them from the next kind. *Perennial* bulbs differ from the foregoing in retaining the products of the condensed axes of several years in a healthy vegetative condition. Thus, if we examine a bulb of the Garden Hyacinth (fig. 16) when it is flowering by its terminal bud, we find the base of the flowering axis surrounded by several leaves belonging to itself; the whole of them stand in the axil of a scale belonging to the preceding year, which also contains the short remnant of the flower-stalk of that year; and to this scale succeed several more, all belonging to that same axis; these moreover stand collectively in the axil of the innermost of a series of scales belonging to the year before, remains of the flower-stalk of which are also sometimes visible. Finally, on examining the axil of the innermost green leaf of the present year, we find, nestled between it and the base of the flower-stalk, the bud which is to form the axis of the next year. Therefore this bulb possesses structures or axes belonging to four distinct generations. The bases of the green leaves expand into fleshy sheathing coats after the flowering of the axis which gives rise to them; and the decay of their blades, which extends to the summit of the bulb, gives rise to the ragged or bitten-off appearance of the latter. These bulbs are *postventitious* like the last kind, but may be distinguished from them as *indefinite.*

48. The *Corm* more or less resembles a bulb externally, but consists principally of a stem with little-developed internodes, thickened into a fleshy body, and bearing leaf-buds at one point, either at the summit, as in the Crocus (fig. 17), or at the side, as in *Colchicum.*

The corm of a Crocus examined very early in spring exhibits a primary axis in the form of a roundish mass bearing the adventitious roots below, and giving rise above to one or several tufts of leaves. The bases of the leaves, outside which are a few membranous scales, being at first sunk in the parent axis, these tufts or rudimentary branches are not readily distinguished as secondary axes; but the terminal bud soon grows out to produce the flower. After the flowering is over, the internodes between the scales and the bases of the green leaves become developed both vertically and also horizontally, so as to convert the base of each flowering stem into a new corm. When about half-grown the new corms stand out as globular bud-like structures on the top of the old corm, which is gradually exhausted, and decays away, so as to set its progeny free. In the axils of the uppermost leaves of the flowering stem are developed new buds (which exist even before the corm begins to sprout in spring); and as the new corms are perfected, the buds imbedded in their summits form the rudiments of the leaves and flowers of the next season, sprouting out in the spring, each to reproduce a corm. Hence in a corm taken out of the ground a short time after the flower withers, we find three sets of axes:—1, the withering parent corm; 2, the young corms branching from this, formed from the bases of the flowering stems; and, 3, the axillary buds of the leaves of the latter, forming the resting buds at the summits of the new corms.

Fig. 17.



Corm of the Garden Crocus, cut through perpendicularly.

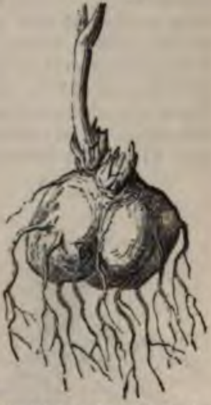
In *Colchicum autumnale* the conditions are somewhat different. When the plant is flowering, in autumn, we find the flowering stem attached to the side of the base of the corm; the flowering stem is surrounded at its base by sheathing scales and rudimentary leaves; in the axils of the two lowest leaves exist minute buds, and the internodes between these leaves are slightly developed. The flowering-stem then withers down to the ground, and during the winter the internode between the two buds swells and forms a new corm, the old one shrivelling up. The leaves appear above ground in the spring, proceeding from the apex of the corm, and the bud at the side of its lower end shoots out to form a new lateral stem, which produces sheaths and rudimentary leaves, and ultimately forms the flowering stem of the next autumn, the base of which repeats the formation of a corm in like manner and shoots up its tuft of leaves in the following spring. The corm being formed from the internode between the buds, the lower of these is, to a certain extent, basilar as well as lateral, while the upper one appears near the top of the perfect corm, rather to one side, near the scar of the old leaves and flower-stalk; this bud may or may not be developed into a corm simultaneously, but in any case it becomes detached from its fellow when the old corm shrivels up, and thus may multiply the plant.

The corm of *Arum maculatum*, examined in spring, exhibits two lobes, with an intermediate constriction; they lie adjoined horizontally: the corm of the past year is shrivelled; the other is solid, and at the summit exhibits sheathing scales enveloping the base of the erect flowering stem. Opening the sheath, which turns upward, we see that the flower arises from a terminal bud, while in the axil of a leaf arising below it exists a bud which is destined to swell up and form a new corm for the next season, the oldest one meantime withering away; so that two generations with the rudiments of the third always coexist; these generations may consist of a greater number of individuals when additional corms arise from the axils of several of the scales of the parent corm.

49. The *Stem-tuber* is either formed from the base of a stem, or from a branch arising from a subterraneous leaf-scale (fig. 19), developed either partially or entirely into a thick and fleshy mass, by expansion of its spongy structure, its own leaves appearing in the form of rudimentary scales, in the axils of which exist dormant buds, or eyes, capable of producing independent stems when the tuber recommences its development after a season of rest.

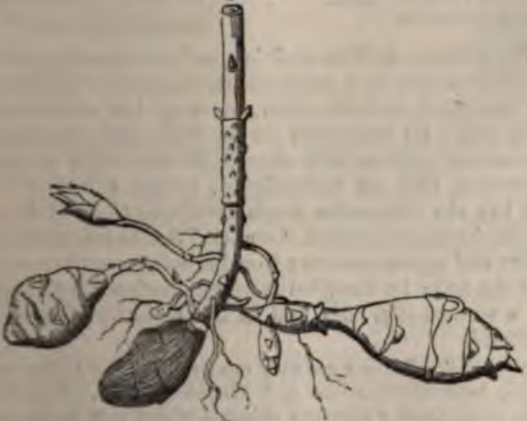
Axial tubers occur in many herbaceous plants, as in *Corydalis bulbosa*; when of annual duration, these are essentially the same as corms. The tuber of the Potato is a familiar example of the stem-tuber formed from a branch, in which its characters may be readily observed; a number of leaf-scales at the base of the "haulm" send out subterraneous branches, which at some distance from the point of origin cease to elongate, and swell up into tuberous masses. The tubers of the Jerusalem Artichoke (fig. 19) are analogous productions. Stem-tubers passing more or less into rhizomes form

Fig. 18.



Root-tuber formed at the base of the stem of *Bunium Bulbocastanum*.

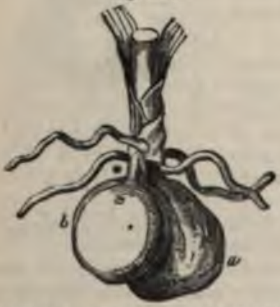
Fig. 19.



Stem-tubers of the Jerusalem Artichoke (*Helianthus tuberosus*).

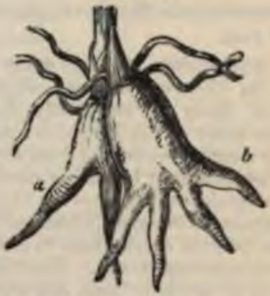
the so-called roots of the Bryonies (*Tamus communis* and *Bryonia dioica*), of the Sweet-potato (*Convolvulus Batatas*), and the species of *Dioscorea* yielding "yams." The tubers of the terrestrial Orchids are chiefly composed of radical structures. If we examine the twin tubers of *Orchis Morio* (fig. 20), we find one at the base of the flowering stem (*a*), which towards the close of the season is withered, while the other (*b*), crowned by a bud (*), is solid and healthy; in the axil of the lowest leaf of this bud exists another bud in a rudimentary state; and as the oldest tuber shrivels, this swells out and assumes its form, in the next season appearing as the bud-tuber, while its parent becomes the tuber of the flowering stem. The greatest part of the mass of these tubers consists of a swollen adventitious root (§ 37), which is intimately blended with a few little-developed stem-internodes and the terminal bud. In some cases these tubers are rounded; in others they are divided below, so as to become *palmate* (fig. 21). The tubers of *Bunium* (fig. 18) belong to the root.

Fig. 20.



Double root-tubers of *Orchis Morio*: *a*, old tuber; *b*, new tuber with the bud * for the next season.

Fig. 21.

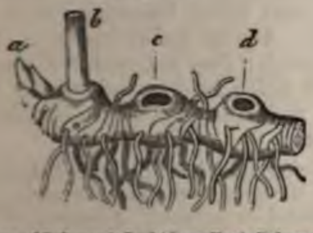


Double palmate root-tubers of *Gymnadenia odoratissima*: *a*, old tuber at the base of the old flower-stem; *b*, new tuber, with bud for the next season.

50. The *Rhizome* or *Root-stock* is a body composed of an indefinite number of corm-like axes permanently connected together, so as to form an elongated, root-like stem, more or less clothed with leaf-scales (fig. 22). Its internodes are generally little developed; sometimes, however, regions with developed internodes alternate with others wherein they are undeveloped, giving a nodose character; when it has the internodes much developed (figs. 11 & 24), it approaches in character (through "runners" &c.) to creeping leafy stems. Its texture and appearance vary from herbaceous or fibrous (fig. 24) to tuberous (fig. 22); its direction is usually horizontal, though in some cases it is vertical (fig. 23); and in the majority of cases it grows under ground.

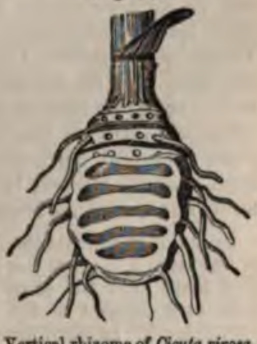
Examples of the rhizome are very numerous among herbaceous perennial plants, both Dicotyledons and Monocotyledons. The Garden-flag affords an example of a tuberous rhizome which may be understood by comparing it with a corm like that of *Arum maculatum*, and by supposing that the older portions of this survive for many years, so as to form a creeping, more or less branched mass. The Solomon's Seal (fig. 22), Sweet-flag (*Acorus*), Ginger, Water-lily, &c. afford other well-known examples. In some of these (called definite rhizomes) the flowers appear to be produced by terminal buds, which take an ascending direction and lose themselves in the inflorescence, the onward growth of the stem being effected by means of axillary buds. In other (indefinite) rhizomes the growth is continuous by the formation year after year of a terminal leaf-bud. Rhizomes of more solid texture, but of analogous construction, occur in many herbaceous Ferns, as in *Aspidium Filix-mas*, also in most of the Rushes (*Juncus*), many Sedges, and a great variety of herbaceous Dicotyledons, such as the Wood-Anemone, the Primrose, *Lathræa squamaria*, &c. Certain widely extending creeping plants afford examples of rhizomes with developed internodes, as the Sand-Sedge (fig. 24), the wire-like rhizome of which extends for many yards under the loose sand, sending up leafy shoots at regular intervals; the stems of Couch-grass, of various Mints, and other Labiate plants; as also of certain Ferns, such as *Lastræa Thelypteris*, *Trichomanes speciosum*, and of the Horsetails (*Equisetum*), &c. When the rhizome is erect it has much of the aspect of a root; and the ordinary form was termed by the old writers a *præmorse* root, the decay of the lower end giving it the appearance of having been gnawed off. Examples of this are not uncommon, as in the *Scabiosa succisa*—in various Umbelliferæ, as *Cicuta virosa* (fig. 23), where the abbreviated internodes form discoid chambers corresponding with the fistular internodes above, and in the Lady-fern (*Athyrium Filix-fœmina*), which consequently rises above ground like a dwarf tree-fern. In *Sparganium ramosum* we meet with a curious alternation of condensed and elongated internodes, so that the rhizomes appear to consist of a number of corms connected together by branches into an erect candelabrum-like assemblage.

Fig. 22.



Rhizome of Solomon's Seal (*Convallaria Polygonatum*): *a*, bud for next year; *b*, flowering stem of the present year; *c* & *d*, scars of the flowering stems of two preceding years.

Fig. 23.

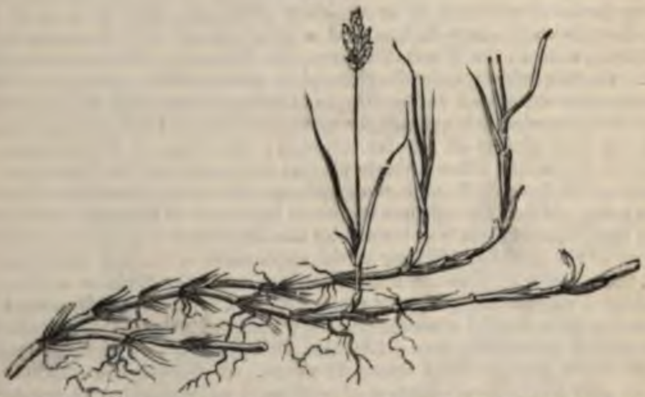


Vertical rhizome of *Cicuta virosa*, cut through perpendicularly.

51. The *Leafy stem*, or region bearing green foliaceous organs, grows above the soil, either in air or water, exposed to the influence of light. Its form and structure are extremely varied, depending chiefly on the mode of development of the internodes, the arrange-

ment of the leaves and mode of development of the buds, and the extent to which its existence is prolonged. The first cause regulates to a great extent the form of the axis, the second the mode of ramification, and the third the size and consistence of the full-grown organ. The principal modifications may be most conveniently studied under the heads of—1. *herbaceous*, and 2. *woody* stems.

Fig. 24.



Sand-Sedge (*Carex arenaria*), the creeping fibrous rhizomes rooting at the nodes and sending up flowering stems.

52. *Herbaceous* stems are produced by annual and biennial plants, and in each successive flowering axis of herbaceous perennials; to these also are analogous the yearling shoots of arborescent plants. Taken by themselves, they are either *annual* or *biennial*; that is to say, they bear on the same axis green leaves belonging either only to one or to two seasons of growth. Annual herbaceous stems alone, of course, occur on true annual plants: they are produced also by those perennial herbaceous plants which send up a flowering stem from beneath the soil in spring; and with these are to be included most plants forming bulbs and corms.

In ordinary annuals the plumule or terminal bud of the seed shoots up at once into a more or less branched flowering stem, and the entire plant dies away after the seeds are perfected in autumn. Examples of this form may be seen in the Poppy, the Sweet Pea, *Veronica hederæfolia* (fig. 12), &c. In many perennial herbaceous plants forming rhizomes, and in most bulbous plants, a subterraneous bud shoots up in the early part of each season of growth, bearing green leaves, and forming a flowering stem (fig. 22 *b*); in the autumn the whole of these structures disappear (*c*, *d*), while resting buds (*a*) are formed in the axils of the lower leaves beneath the soil, to repeat the growth in the following season. We have examples of this kind of stem in the Solomon's Seal, Garden Pæony, Aconite, Anemone, Asparagus, &c. The young fleshy shoot with rudimentary leaves which these plants form in early spring is sometimes called a *turio* (this is exemplified in the edible part of Asparagus). The leafy flowering stems of bulbs and tubers, such as those of the Lily, Potato, *Orchis*, &c., furnish further examples of the annual herbaceous stem.

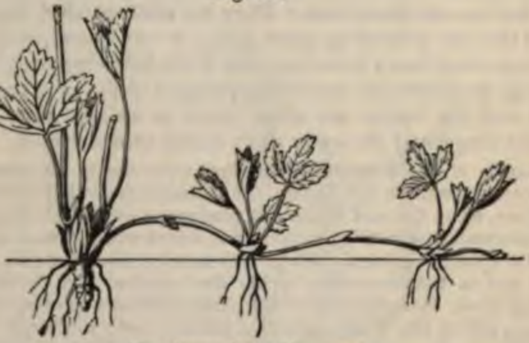
53. Biennial herbaceous stems are found in true biennials and many herbaceous perennials. They are distinguished by the lower part of the axis producing green leaves in one season, and the upper portion growing into a flowering stem in the following year. Generally speaking, the internodes are little developed in the growth of the first season, and the leaves are often larger as well as more crowded; they also frequently die away early in the second season.

Examples of the biennial herbaceous stem are to be found in such true biennial plants as the Turnip, the Canterbury Bell, Thistle, Parsley, &c. Here, when the seed is sown, it produces a stem with scarcely developed internodes, supporting a number of leaves which form a kind of tuft or rosette upon the ground; this growth remains almost at rest during the winter, and in the succeeding spring the terminal bud shoots up into a flowering stem. Sometimes several axillary buds also grow up into flowering stems, giving rise to the condition called "*radix multiceps*:" this may occur either in biennials or perennials. A similar kind of stem is found in such perennial herbaceous plants as the common Daisy, the Garden Flag, the Dandelion, &c., where axillary buds are produced at the base of the dying flowering stem in autumn, and grow up above ground at once to form leafy tufts, lasting through the winter, and giving birth to flowering stems in the next season.

54. The leafy shoots of perennial plants, with their axis and adventitious roots, may be separated artificially, and used for propagating the plant (gardeners call this "parting the roots"); and certain plants are naturally multiplied in the same way, by buds or branches which have received special names. Thus the herbaceous flowering stems of the House-leeks (*Sempervivum*), after flowering, produce buds in the axils of their lower leaves which expand into leafy rosettes. The parent stem dying down, these are thrown off as detached plants, and strike root; in the following season they send up a flowering stalk and repeat the process. The separating tuft formed in the autumn is called an *offset*. The Strawberry-plant in like manner produces, in the axils of its leaves, buds which in the same season expand several of their internodes, and form long filiform branches, the buds of which give rise to rosettes of leaves, and strike root, and thus form independent plants: such shoots are called *runners* (fig. 25). In all these cases the herbaceous flowering stem is of two years' growth, its branching portion belonging to the autumn, the ascending flowering portion to the succeeding spring or summer.

Special names have been given to certain forms of the herbaceous stems, some of which are not very definite. Botanists sometimes call the stem of Grasses a *culm*; agriculturists term both this and the stems of herbaceous plants generally "haulm," which, in its original language, is synonymous with *culmus*. Neither term is perhaps requisite; but, if used, the term culm (*culmus*) should be applied to the unbranched stems of Grasses; haulm (*caulis herbaceus*) to all other herbaceous stems with well-developed internodes.

Fig. 25.



Strawberry-plant with runners.

55. The *Woody* stem, characteristic of arborescent plants, presents itself in two principal classes of form:—one, where it is branched, constituting a *trunk* (*truncus*); the other, where it is an unbranched column, bearing its foliage as a terminal crown, forming what is called a *stock* (*caudex*).

These differences depend upon the mode of development of the buds: when, as in Dicotyledonous trees generally, axillary buds are developed into branches, we find a ramified trunk; when the terminal bud alone unfolds, as in most Palms, the globular and columnar Cactaceæ, and the Cycadaceæ, a simple columnar caudex is formed.

56. The *Trunk* of arborescent plants arises as an herbaceous stem from the seed, but usually becomes more or less woody before the close of the first season; in the autumn it ceases to develope internodes at its point, and the terminal bud closes up into a resting winter-bud enclosed in leaf-scales; buds of the same sort are produced in the axils of the leaves; and all or part of them open in the following spring, to produce a second generation of axes in the form of shoots; the same process being indefinitely repeated, a branched trunk is produced. If the central stem is not much elongated, and the lateral ramifications are numerous, the result is a shrubby plant (*dumus*); if the growth of the main trunk predominates for a long time, but ultimately slackens, and the side branches grow more, the form seen in ordinary trees appears (*arbor cymosa*); while if the growth of the central stem by the terminal bud is predominant throughout life, we have tall straight trunks with comparatively small branches, such

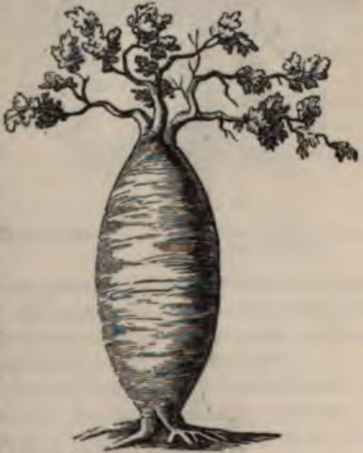
as are seen in the Lombardy Poplar and many Pines and Firs (*arbor fastigiata*).

Besides the diversity in the relative development of terminal and lateral buds, a great variety of conditions occur in the mode of unfolding of the buds and in the destination of their products. By no means all of the axillary buds of arborescent stems come to development; and they are sometimes suppressed in definite order: this, and the mode of arrangement of the leaves which subtend them, has much influence on the general form of the ramification.

Attention may here also be particularly directed to the *definite* and *indefinite* development of the axes. In many trees, such as the Oak, the Birch, the Ash, many Pines, &c., the terminal bud of each shoot, if healthy, opens out every spring, and developes a new length in the same direction; so that, on such branches, the successive years' growths are distinguishable for a more or less considerable time by the scars of the leaf-scales which enveloped the successive winter buds. When these trees flower, their blossom emerges from an axillary bud. In other trees, such as the Horse-chestnut and the Lilac, the winter bud contains a rudimentary shoot, the terminal bud of which produces an inflorescence, and consequently this bud is evolved into a leafy shoot, the growth of which in length is arrested for ever by the terminal blossom, and the shoots of the succeeding year must arise from axillary buds at its sides. The branching of such trees presents a peculiarly bifurcated appearance. The same condition is produced in *indefinite* trees when the terminal buds of their shoots are killed by frosts.

The originally cylindrical form of trunks often undergoes considerable alteration with age, depending upon peculiar modes of development of the woody structure within. Irregular prominences occur commonly on such old timber-trees as have large branches, greater enlargement taking place in the line between the base of the branches and the roots; this is often seen on old Oaks. Some tropical trees produce vast buttress-like projections in the same way. The forms of the trunk of the woody climbing plants of tropical forests present very remarkable irregularities, arising either from a twining habit, or from irregular development caused from lateral pressure or otherwise. In some kinds of *Bombax* (fig. 26), and in *Delabechea* (Bombaceæ), the trunk is swollen out in the shape of a great flask between the root and the main branches.

Fig. 26.



Trunk of a Brazilian *Bombax*.

57. The *Stock* or *caudex* is an undivided woody trunk, produced by the annual unfolding of a single terminal bud. Its

internodes are commonly little developed, so that its sides are marked with the scars of its fallen leaves; sometimes, however, the internodes are developed, and then the stock has a jointed appearance, from scars or actual articulations at the nodes. The stocks of the Cactaceæ are remarkable for their form and consistence; their lateral buds are developed into tufts of spines, which are the representatives of the leaves of undeveloped branches.

The stock of the Palms exhibits considerable variety of form. In the Cocoanut- (*Cocos*) and Date-palms the internodes are scarcely developed, and the scars of the leaf-stalks, arranged in spiral order, cover the sides; the same holds good of the stock of *Cycas* and its allies, of *Xanthorrhæa*, *Kingia*, and other arborescent Monocotyledons, and also of the stock of the Tree ferns (fig. 29). In other cases an internode is more or less developed between each leaf, and the stem is smooth, but marked by a succession of scars running nearly round the stem, as in *Mauritia* and *Astrocaryum vulgare*; in *Geonoma* and *Chamædorea* the internodes are developed and the nodes thickened, so as to appear externally somewhat like those of the stems of Grasses, but they are not really articulated nor hollow like the latter. The *caudex* of the Palms furnishing the common Cane (*Calamus*) is chiefly distinguished from the last by the slenderness and extreme length of the internodes. Many of these Palm-stocks, which are simple in their principal mass, send out axillary buds at or below the

Fig. 27.

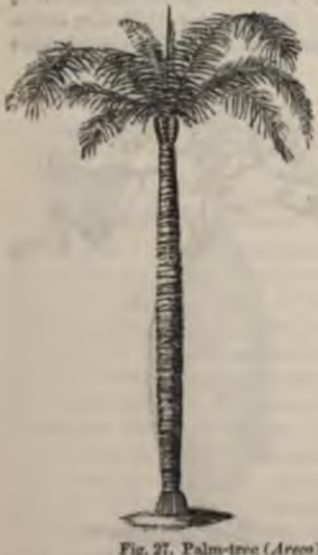


Fig. 28.

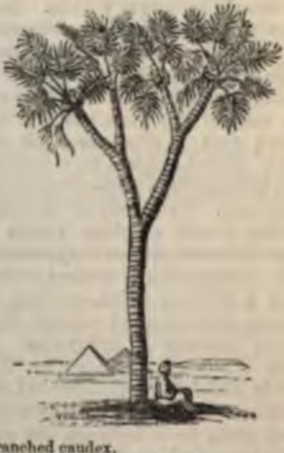


Fig. 27. Palm-tree (*Areca*) with unbranched caudex.
Fig. 28. Branched trunk of the Doum Palm (*Hyphæne thebaica*).

ground, which form runners, and ultimately grow up independently of the parent. The aërial stocks of a few branch high above the ground, as in the Doum-palm (fig. 28), and in *Pandanus* (fig. 9), where the terminal bud appears to undergo successive bifurcations, but really sends off at intervals single axillary buds, the development of which soon equals that of the parent axis, and causes the deflection of the latter so as to give a forked appearance. A similar mode of growth is observed in certain Hæmodoraceæ (arborescent Monocotyledons, natives of S. America), also in the Liliaceous genus *Yucca*. The stocks of some of the Cactaceæ are undivided, as in *Melocactus* (fig. 31), *Echinocactus*, and *Mamillaria*, &c.; but in others a few branches arise, giving a compound character, as in various species of *Cereus* (fig. 32), and in the leaf-like stalks of *Opuntia* (fig. 30). Analogous structures occur in foreign species of *Euphorbia*. The Elephant's-foot plant (*Tamus elephantipes*) possesses an extraordinary stock, consisting of a large and solid woody mass of rugged appearance and perennial growth, from which slender annual climbing stems arise, dying down again each season, while the stock slowly increases in size.

Fig. 29.

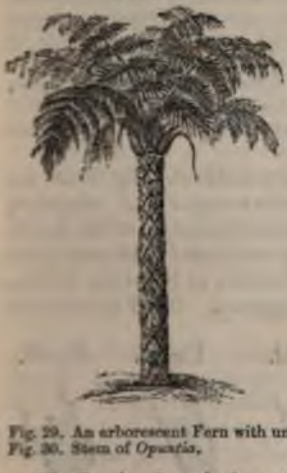


Fig. 30. Fig. 31. Fig. 32.

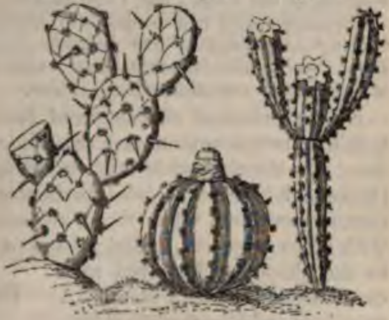


Fig. 29. An arborescent Fern with unbranched caudex.
Fig. 30. Stem of *Opuntia*.

Fig. 31. Stem of *Melocactus*.
Fig. 32. Stem of *Cereus*.

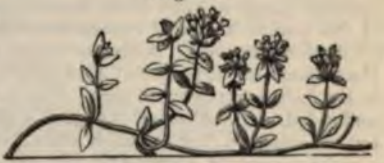
58. In the description of stems generally, certain technical terms are in use, in addition to those above explained. These refer principally to—a. *consistence*; b. *direction and habit of growth*; c. *form*; d. *condition of surface*; e. *ramification*; and f. *dimensions*.

*a.* The terms *herbaceous* (*herbaceus*) and *woody* (*lignosus*) need no further definition. Some stems are *fleshy* or *succulent* (*carnosus*) as in *Cactus*, &c. Most stems are *solid* (*solidus*); those of the majority of Grasses and the Umbelliferæ (Carrot, Celery, &c.), and the Horsetails (*Equisetum*) are *hollow* or *tubular* (*fistulosus*).

*b.* Stems may be truly *erect* (*strictus*), *flexuous* (*flexuosus*), or *nod-*

*ding* (*nutans*), which in trees becomes *overhanging* (*cernuus*). Stems which turn upwards from a horizontal base are called *ascending* (*ascendens*); those lying along the ground without rooting are *procumbent* or *prostrate* (*decumbens, procumbens, humifusus*) (fig. 33); if a prostrate stem roots at its nodes, it becomes *creeping* (*repens*). Slender stems neither lying on the ground nor creeping may be *pendent* (*pendulus*) when growing on rocks &c., and *floating* (*fluitans*) when growing in water. Weak stems also rise from the ground as *climbing* (*scandens*) or *twining* (*volubilis*) stems.

Fig. 33.



Procumbent stem of Thyme.

Climbing stems support themselves in various ways:—the Ivy by tufts of adventitious roots, which attach themselves firmly to foreign bodies; the climbing species of *Clematis*, the Canary-creeper (*Tropæolum peregrinum*) by hooking their leaf-stalks round the support; other plants by *tendrils*, as the Vine, Peas, Cucurbitaceæ, &c.

Twining stems coil themselves spirally round the supporting body, turning sometimes in one direction, sometimes in the other, as in the Hop, Convolvulus, *Cuscuta*, &c. Some of the tropical twiners produce woody trunks resembling large cables.

*c.* The principal characters of form are designated by terms requiring no explanation, such as *cylindrical* or *terete, conical, columnar*, &c. If a stem presents thickenings opposite the origin of the leaves (nodes), it is called *jointed* (*articulatus*) or *knotted* (*nodosus*); the reverse condition, when there are constrictions at intervals, is also, with more propriety, called *jointed* (*articulatus*). Other terms refer to the shape as displayed in a cross section of the stem. A stem is *round* (*teres*) when it presents a circular section; *compressed* (*compressus*) when the section is elliptical; *angular* when the section is polygonal, under which head are distinguished, in a three-angled stem for example, *triquetrous* if the three angles are sharp (fig. 34), *triangular* if they are about right angles, and *trigonous* when the angles are obtuse or rounded off. When the surface presents a great number of longitudinal ridges, it is called *ribbed* (fig. 36); numerous longitudinal grooves render it *furrowed* (*sulcatus*). In some cases the projecting angles of stems are *winged* (*alatus*), as in many Thistles; in other cases the stem or

Fig. 34.

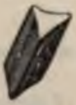


Fig. 35.

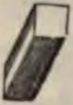


Fig. 36.

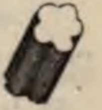


Fig. 34. A triquetrous stem.
Fig. 35. A quadrilateral or square stem.
Fig. 36. A ribbed stem.

branch is flattened so as to resemble a leaf, in which case the term *cladode* is applied.

*d.* The surface of a stem may be *smooth* (*lævis*) or *striate* (*striatus*), *i. e.* marked with fine grooves and ridges. It may be devoid of epidermal appendages or *glabrous* (*glaber*), or furnished with a more or less dense coat of hairs (*pilosus, hirsutus, lanatus,* &c.), or it may be set with bristles (*setosus*), glandular or otherwise, or with thorns (*spinosus*).

Similar terms are still more commonly applied to the surfaces of *leaves*, under which head they will be more minutely defined.

*e.* A stem is either *simple* or *branched*; if the ramification is excessive, it is called *much-branched* (*ramosissimus*). The branches may be *erect*, *spreading* (*patens*), *outstretched* (*divaricatus, patentissimus*), *deflexed* (*deflexus*), or *pendulous* (*pendulus*). These qualities especially affect the crown of trees, which is sometimes called their *cyme*.

*f.* Different terms are applied to plants with woody stems, according to their division and mode of branching. A *tree* (*arbor*) is a plant with a woody trunk and branched head, above 25 feet in height. A *small tree* (*arbusculus*) is a similar plant, which never rises above 25 feet in height. A *shrub* (*frutex*) is a kind of dwarf tree, where the main trunk is little developed, and the whole never attains a height of more than 15 feet. *Under-shrub* (*fruticulus*) is the diminutive of this, applied to kinds which do not exceed 3 feet in height. A *bush* (*dumus*) is a kind of shrub where the principal axis is not readily distinguishable, the lateral branches being developed very freely close to the ground, so as to hide the main stem.

## Sect. 4. THE LEAF.

59. Leaves are the lateral organs attached to the ascending portion of the axis, and in general are flat, expanded plates, produced directly from the superficial part of the stem, and from which, after a certain term of existence, they are removed, either by breaking off at a distinct joint, or by decay.

In some cases, as in Cactus (figs. 30–32), the true leaves are absent, their office being filled by the green rind of the stem. Normal leaves, belonging to the vegetative system, are alone taken into account in this chapter; the modified foliar organs composing flowers must be treated separately.

60. The leaves arise from and mark the *nodes* (§ 44) of the stem; and it has been already stated that it is at the nodes, in the *axils* of leaves (§ 43), that lateral or axillary buds are as a general rule produced. From this it follows that the *arrangement* of the leaves must be of great importance, not only in reference to their own re-

lative positions, but as determining more or less completely the plans of ramification of stems. It is found that the modes of arrangement of leaves are in accordance with certain general laws; and a particular study of these laws has been pursued, under the name of PHYLLOTAXY.

61. Leaves exhibit two principal types of arrangement: either they are solitary, one only occurring at a node, or two or more spring from the stem at the same level. When the leaves stand alone, they are said to be *alternate* or *scattered* (fig. 37); where two stand at the same level, facing one another, they are called *opposite* (fig. 38); and if more than two originate from one node, forming a circle, the leaves are called *whorled* or *verticillate*. Very rarely two leaves appear to spring from the same node, as in what are called *geminate* leaves (*Solanum*). This condition is supposed to arise from irregular displacement and partial adherence of one of the leaves to the stem.

Fig. 37.

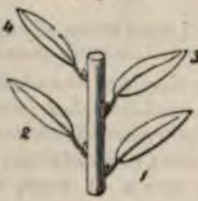


Fig. 38.

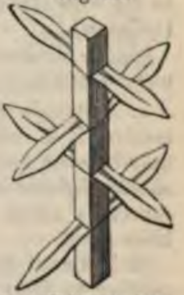


Fig. 37. Diagram of the arrangement of alternate distichous leaves.

Fig. 38. Diagram of the arrangement of decussate opposite and tetrastichous leaves.

Really whorled leaves are not so common as is sometimes imagined, the whorled condition being imitated in some cases, as in many Stellatæ, by an excessive development of interfoliar stipules; truly whorled leaves are seen in *Paris* and *Myriophyllum*. Representatives of the two principal types are found in the embryo of Monocotyledons and Dicotyledons—the former having a solitary *cotyledon*, the latter having two, placed the one opposite to the other (fig. 2); but this opposite arrangement of the cotyledons is not always associated with a like disposition of the true leaves.

62. *Alternate leaves* exhibit many modifications of arrangement. Sometimes they are truly alternate; that is, the second leaf is exactly on the opposite side of the stem from the first, and the third exactly over the first: a series of leaves arranged in this way form two perpendicular rows. Such leaves are termed *distichous* or *two-ranked* (fig. 37); examples of which are found in the Grasses.

If the second leaf is not opposite to the first, but at a point distant from it one-third of the circumference of the stem, and the third leaf one-third further round, the fourth leaf, likewise distant one-third from the preceding, will stand over the first. Leaves so arranged form three perpendicular rows, constituting the *tristichous* or *three-ranked* arrangement, which is common among the Monocotyledons (fig. 39).

63. Now, when a line is drawn round the stem so as to pass regularly from leaf to leaf, we find that its course is *spiral*. In the *distichous* case the spiral line commencing at any given leaf completes one circuit and commences a new one at the third leaf; in the *tristichous* arrangement the spiral completes one circuit and commences a new one with the fourth leaf (fig. 39). The series of leaves included by the spiral line in passing from the first leaf to that which stands directly above it is called a *cycle* (fig. 40); the fraction of the circumference of the stem, which measures the distance between any two succeeding leaves in a cycle, is termed the *angular divergence*, which in the distichous case is one-half ($\frac{1}{2}$), in the tristichous one-third ($\frac{1}{3}$). These fractions not only represent the angular divergence, but also the entire character of the arrangement; for the numerator, as is seen, indicates the number of turns of the spiral forming a cycle, while the denominator expresses the number of leaves in that cycle.

In the *pentastichous*, *quincuncial*, or *five-ranked* arrangement of leaves the conditions are more complex. The sixth leaf of course stands over the first (figs. 41 & 42), commencing a second cycle; but the spiral line passing through the first five leaves makes *two* circuits round the stem; moreover the successive leaves stand at a distance from each other of two-fifths of the circumference of the stem; and therefore the expression of the angular divergence, $\frac{2}{5}$, in-

Fig. 39.

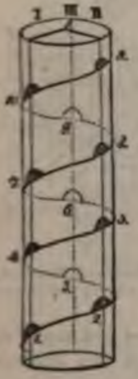


Fig. 40.

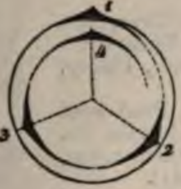


Fig. 41.

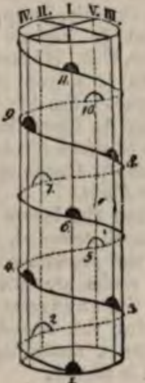


Fig. 42.

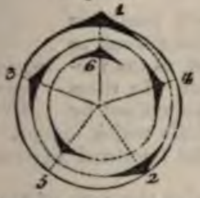


Fig. 39. Projection of the $\frac{1}{3}$ arrangement.
Fig. 40. Horizontal projection of a cycle of the $\frac{1}{3}$ arrangement.
Fig. 41. Projection of the $\frac{2}{5}$ arrangement.
Fig. 42. Horizontal projection of a cycle of the $\frac{2}{5}$ arrangement.

dicates also the number of turns round the stem in the cycle, and the number of leaves in the cycle, as before.

The relations here existing are found to hold good when further carried out. The next degree of complexity of the arrangement is where eight perpendicular rows of leaves exist, and the ninth leaf is over the first. In this case the spiral takes *three* turns in completing the cycle; and the expression $\frac{3}{8}$, denoting the turns of the spiral and the number of leaves in a cycle, also corresponds to the angular divergence of the successive leaves.

When we place the foregoing figures together, thus: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, it will be observed that each fraction has its numerator composed of the sum of the numerators of the two preceding fractions, and its denominator of the sum of the two preceding denominators; and it is really found that all higher complications, in normal conditions of stems, exhibit some further indication of the same ratio, and are marked successively by $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, $\frac{21}{55}$, &c.

The simpler forms of arrangement are the most common; those marked by higher fractions are chiefly found in plants with the leaves much crowded, as in the House-leek and its allies. The scales of the cones of Pines and Firs offer most beautiful examples of these spiral arrangements. The following examples may be mentioned for observation:—

Plan $\frac{1}{2}$. Leaves of Grasses, *Iris*, *Gladiolus*, Elm, Lime, &c.

Plan $\frac{1}{3}$. Leaves of Sedges (*Carex*, *Scirpus*), Orchids, Tulip, Alder, Birch, &c.

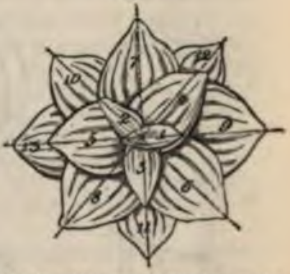
Plan $\frac{2}{5}$. Leaves of Apple, Cherry, Poplar, Oak, Walnut, &c.

Plan $\frac{3}{8}$. Leaves of Flax, Road-weed (*Plantago*) (fig. 43), Holly, Aconite, &c.

Plan $\frac{5}{13}$. Eyes (buds) of Potato-tubers, cones of *Pinus Strobus* (fig. 44).

Plan $\frac{8}{21}$. Cones of Larch (*L. europæa*), *Pinus Picea*.

Fig. 43.

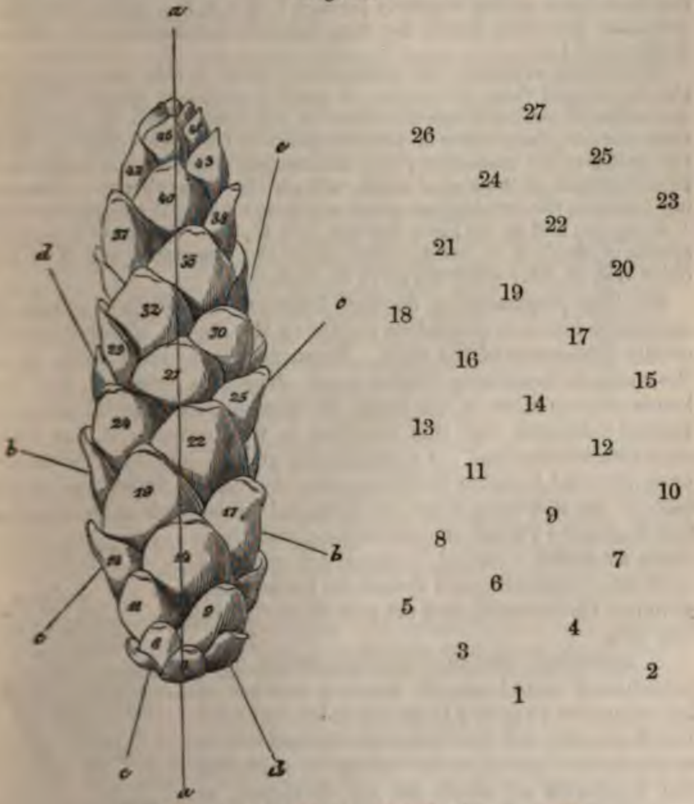


Rosette of leaves of *Plantago media*, seen from above; the leaves on the $\frac{3}{8}$ type.

When the leaves are very numerous and much crowded, it is often difficult to trace the *fundamental spiral*, as the vertical ranks are not evident. In these cases the arrangement is ascertained by studying the *secondary* spirals which appear. These are more or less numerous, according as the fractional expression of the fundamental spiral is higher.

For example, in examining the cone of the White Pine, a complex spiral arrangement is at once recognized, which will be understood by reference to the adjoining diagram (fig. 44). Starting from the lowest scale, as 1, and tracing up a flat spiral line to the *left* hand (fig. 44 *b–b*), we find that it will leave untouched a similar spiral series, running in the same direction, between its turns; these two spirals together will include all the scales of the cone; and if we number the successive scales of the first spiral 1, 3, 5, 7, &c., always with a difference of 2, and then those of the second spiral 2, 4, 6, 8, 10, &c., we define our first two secondary spirals. Next we shall find, that by passing through 1, 4, 7, 10 (fig. 44 *c–c*), &c., we mark a spiral running to the right hand, more oblique than the first two, and we find that there are two other spirals parallel to this right-hand spiral, running through 3, 6, 9, 12, &c., and 2, 5, 8, 11, &c., making *three* of these right-hand spirals, whose scales have numbers increasing by three at each step. Next, turning to the left again, we find a

Fig. 44.



Cone of *Pinus Strobus*, with the scales in the $\frac{5}{13}$ arrangement.

still steeper spiral ascending from 1 through 6, 11, 16 (fig. 44 *d–d*), &c., the numbers in the scale having a common difference of 5, while five of these spirals are found lying parallel, viz. running through 2, 7, 12, &c., 3, 8, 13, &c., 4, 9, 14, &c., and 5, 10, 15, &c. Fourthly, we take another spiral line to the *right*, through 1, 9, 17, 25 (fig. 44 *e–e*), and we find eight spirals of this order, the other seven being numbered respectively 2, 10, 18,

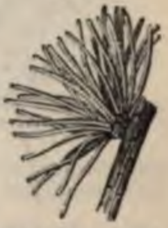
&c., 3, 11, 19, &c., 4, 12, 20, &c., 5, 13, 21, &c., 6, 14, 22, &c., 7, 15, 23, &c., and 8, 16, 24, &c. If we attempt to find another spiral between the right-hand, 1, 9, 17, &c., and the last left-hand one, 1, 6, 11, &c., we find that we go from 1 to 14, and this stands directly over 1 (fig. 44 *a–a*). It therefore completes the fundamental spiral of the whole arrangement: the difference between it and 1 (13) gives the denominator of the fraction expressing the arrangement; and, as has been shown above, the regular numerator of this number is 5, making $\frac{5}{13}$. And in this case we shall find that a line passing regularly through 1, 2, 3, 4, &c., to the left-hand, will make five turns round the cone before it terminates at 14, immediately over 1.

The fraction expressing the fundamental spiral in this case, $\frac{5}{13}$, might also be deduced from the number of parallel secondary spirals. Taking the orders of secondary spirals nearest to the vertical line, on each side, right and left, the number of parallel spirals of the lower order of these two will give the numerator; and this number, added to the number of parallel spirals of the higher order, will give the denominator. Thus, in our example, the two highest orders are those running to the left through 1, 6, 11, &c., and to the right through 1, 9, 17, &c. There are 5 parallel spirals of the 1, 6, 11 order, which gives the numerator, and 8 of the order 1, 9, 17, &c.; and 8+5 gives 13, $=\frac{5}{13}$.

64. The perpendicular distance between the points of origin of successive leaves is dependent simply on the degree of development of the internodes of the stem. These may be so short that, as in the common Stone-crop (*Sedum acre*), *Araucaria imbricata*, &c., the leaves overlap more or less along the developed axis; such leaves are termed *imbricate*; and this condition is very common in the leaf-scale forms of the leaf. A great number of well-developed leaves are often crowded together by the non-development of internodes at the base of the flowering stems of perennial herbs, such as the various Saxifrages, the Turnip, Dandelion, &c.; and where these so-called "radical" leaves are arranged with some regularity, and spread out horizontally as in the House-leeks, they are said to be *rosulate* (fig. 43).

A somewhat similar condition occurs upon branches of some trees, on which a number of leaves appear to spring from one point, as in the Larch (fig. 45) and the Berberry; the collections of *fasciculate* leaves really belong to a branch the internodes of which are not developed, so that they all spring at once from the leaf-axil in which the branch-bud was formed.

Fig. 45.



Fasciculate leaves of the Larch.

In other Conifers, the number of leaves in these bundles is smaller, and very regular and characteristic; *e.g.*, in *Pinus sylvestris* two leaves are thus associated, in *P. Cembra* three, in *P. Strobus* five, &c. In those buds of the Larch which afterwards unfold into shoots, the transition from a *fasciculate* into a regular spiral arrangement becomes evident.

65. *Opposite and whorled leaves* likewise exhibit great regularity. The number of leaves in a whorl is here also sometimes expressed by a fraction, which is enclosed in a parenthesis; the denominator in this case indicates the number of leaves in one circle.

Examples of these in true leaves are furnished by the following plants.
($\frac{1}{2}$) plan (opposite leaves). Pinks, Labiatæ.
($\frac{1}{3}$) „ *Lysimachia vulgaris, Myrica Gale, Trillium.*
($\frac{1}{4}$) „ *Paris quadrifolia.*
($\frac{1}{5}$) „ *Myriophyllum pectinatum.*
Sometimes the numbers vary on different parts of the same stem, as in *Hippuris.*

66. When leaves are opposite, the pairs are mostly alternate; that is, they cross at right angles, the third pair standing over the first. Such leaves are called *decussate* (fig. 46). With whorls of three leaves, again, we usually find a similar alternation; the leaves of the second whorl stand over the intervals between those of the first, the leaves of the third whorl standing over the leaves of the first. In each of these cases, therefore, we have a kind of cycle; and other cases occur in which the cycles are not completed by two whorls, but the leaves of the 3rd, 5th, 8th, 13th whorl, &c. stand directly over those of the first. This shows the existence of a spiral plan analogous to that regulating the arrangement of alternate leaves, with the same numerical ratios; and these many-whorled cycles exhibit secondary spirals analogous to those of the higher plans of the alternate leaves. In many fossil plants the pairs of leaves do not alternate, but are placed directly one over the other.

Fig. 46.

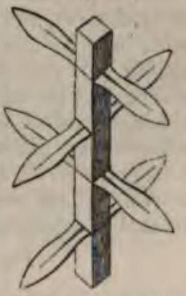


Diagram of decussating pairs of leaves.

It is evident that if the internodes between the component leaves of any individual spiral cycle were undeveloped, while those between *successive* cycles were lengthened, a verticillate arrangement would result. In certain plants (for example, the Myrtle, the Antirrhinum) alternate and opposite leaves occur on the same stem. This is the case also in those Dicotyledons where the true leaves succeeding the opposite cotyledons are alternate, as in the Scarlet Bean, Mustard, &c. The arrangement of the leaves in the manner above indicated is to a great extent connected with the disposition of the fibro-vascular bundles of the stem. It should, however, be stated that the arrangement of the leaves on the stem is not always the same as that on the branches.

67. Certain terms are in common use in descriptive works to indicate the absolute position of leaves upon the stem. The name *radical* leaves is applied to those, usually of larger size than the rest, which are often found collected at the base of flowering stems of herbaceous plants, such as the Dandelion, Lettuce, Turnip, *Plantago*

(fig, 10), &c. The ordinary leaves of the stem are sometimes distinguished as *cauline* or *stem-leaves*, while the term *ramal* is occasionally used for those on the shoots of trees and shrubs when these present special characters.

The leaves belonging to the inflorescence are called bracts. Their phyllotaxy agrees with that of the stem-leaves.

68. The point where a leaf springs from the stem is commonly called the *insertion*. Leaves are either *articulated* there, separating when dead by a distinctly characterized line of fracture, or they merely wither down, and leave their bases as a ragged covering to the stem; the latter condition occurs mostly in leaves with sheathing bases.

69. A perfect leaf is divisible into two regions (fig. 47)—the *blade* or *lamina* (*b*), and the *leaf-stalk* or *petiole* (*c*); the latter, when present, may be more or less completely represented by a *sheath* or *vagina* (*a*), partly or wholly embracing the stem from which it arises. At the base of the petiole often occur distinct leaf-like appendages, called *stipules*. All parts of the leaf—blade, stalk, and stipules—are much subject to modification, and may even exist in the forms of *tendrils*, *spines*, *pitcher-like* organs, &c., very unlike regular leaves. These metamorphosed leaves, or parts of leaves, are best treated of separately.

Fig. 47.

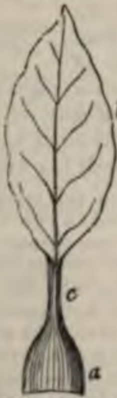
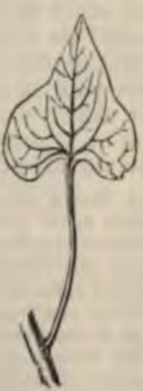


Diagram of the regions of a leaf: *a*, sheath; *b*, blade; *c*, stalk.

Fig. 48.



A stalked leaf.

The stalk-like petiole (fig. 48), most common in Dicotyledons, always has the base slightly widened out at its point of emergence from the stem; in the leaves of Palms, the Banana, Scitamineæ, &c., the base is expanded so as to embrace the stem, while in the Grasses the petiole is entirely represented by a sheath (fig. 52). The green part of the leaves of the Hyacinth and other bulbous plants is the blade, and will be found nuous below with a colourless, fleshy, petiolar portion, forming one e "coats" or sheaths of the bulb (fig. 16).

). The leaf may, however, be represented by one only of the ons. It is very common to find leaves without distinct petioles, blade springing directly from the stem; such leaves are called *le* (fig. 49). On the other hand, the petiolar region may exist out the blade; and among the cases of this sort a considerable ety of conditions is met with. Petiolar structures, devoid of næ, and more or less reduced to scales or membranous sheaths, commonly found on subterraneous stem-structures, such as s, rhizomes, &c., whence we have denominated this part of the the "leaf-scale region" (§ 45). Similar scales appear in place een leaves in the "true-leaf" region of various parasitic plants, as *Orobanche*, in which the leaves have no physiological function erform; and they recur periodically on the stems of arborescent ts which form winter-buds, in the shape of bud-scales. In the -leaf region the blade is either supported on a stalk-like or thing petiole, or is sessile. The sessile condition is generally e common toward the upper part of stems and shoots; and in *bracts* or leaves belonging to the inflorescence the petiolar region mparatively seldom developed. The first leaf (*Vorblatt* of the mans) on a branch in many Monocotyledons, and in some Dicotyns, is of a different form from the rest.

1. In some families the true-leaf region is clothed with petioles anded into the form of laminæ; these are called *phyllodes* (figs. & 51), and in such cases the true laminar region is often partially ntirely suppressed.

Fig. 50.

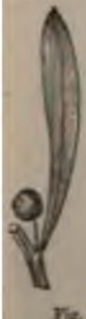


Fig. 49.

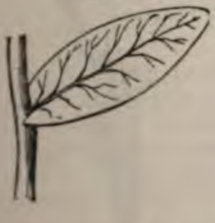


Fig. 51.

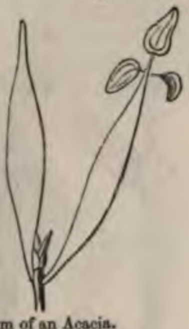


Fig. 49. A sessile leaf. Fig. 50. Phyllodium of an Acacia.
Fig. 51. Two phyllodia of *Oxalis latipes*, one with a ternate blade.

The transition from the petiolar leaf-scale organs into perfect leaves h sheathing petioles may be observed not only in bulbs, but in many ases with creeping stems, which exhibit, at the junction of the leaf-scale and true-leaf regions, sheaths surmounted by short green lancet-shaped laminæ, increasing in length in successive leaves.

72. When the petiole appears as a distinct leaf-stalk, it is often accompanied by a pair of more or less distinct foliaceous appendages at its base, called *stipules*. When these exist, the leaf is called *stipulate* (fig. 56); when they are absent, *exstipulate*.

The presence or absence of stipules is often a very regular character of Natural Orders. The various forms of stipulate petioles form a kind of transition to the petioles with sheathing bases.

73. The *petiole* is usually of semicylindrical form, with the flat surface above; not unfrequently the upper surface is channelled (*canaliculate*), giving a more or less crescentic section; in a few instances, especially in the Aspen, it is laterally compressed. Where it is round or cylindrical its structure is like that of a branch.

The stalk-like petiole is either *simple*, when it supports a single blade, or it is branched or *compound*, when the blade is composed of a number of distinct leaflets; the branches are sometimes called *partial petioles*, and may even be articulated at their points of origin from the primary petiole.

Compound petioles supporting the leaflets of compound leaves are known from branches by arising independently from the stem, by having buds in their axils, and by the absence of any indication of a leaf immediately beneath them.

74. The flattened or leaf-like petiole, called a *phyllode*, resembles a lamina, but is known by standing edgewise on the stem—that is, with its flat faces parallel with the direction of the stem; in some cases *phyllodes* exist without true laminæ, in others the laminæ are more or less developed at the summit (fig. 51).

Fig. 52.

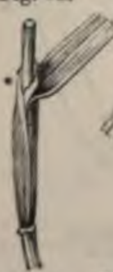


Fig. 53.

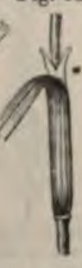


Fig. 54.

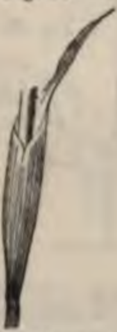


Fig. 55.

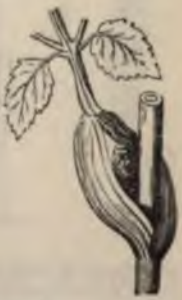


Fig. 52. Leaf-sheath of a Grass, with an entire *ligula*.
Fig. 53. Leaf-sheath of a Grass, with a bifid *ligula*.
Fig. 54. Leaf-sheath of *Eriophorum*.
Fig. 55. Sheathing base of the petiole of *Angelica*.

Striking examples of *phyllodia* with or without laminæ are furnished by various species of *Acacia* (figs. 50 & 96), in many of which the blade is present, compound and bipinnate.

75. The sheathing portion or *vagina* is the only portion of the petiole which is developed in certain plants, as in the Grasses and Sedges (figs. 52–54), in which it forms a complete sheath to the stem, and passes at once into the blade at the top: this sheath is merely rolled round the stem in the Grasses; but its margins are confluent, so as to form a tube, in the Sedges. The vaginal petiolar region is more or less distinctly evident in many Monocotyledonous leaves which at first sight appear to be sessile, as in the Tulip, Hyacinth, &c.; and it is generally more or less developed at the base where a distinct leaf-stalk exists in this class, as in the Palms and, above all, in the Musaceæ. In many Dicotyledons also the base of the stalk-like petiole is enlarged into a sheath, as in Umbellifers (fig. 55).

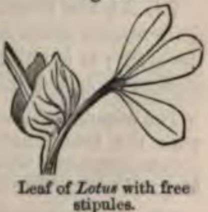
76. Sometimes the stalk-like petiole is *winged* (*alate*), as when a narrow plate of the blade structure springs from its margins; in certain cases these wings are *decurrent* down (or, rather, are continuous with the sides of) the stem from which the leaf arises, as in many Thistles, *Verbascum*, &c., producing a *winged* or *alate* stem.

77. The petiole is ordinarily more or less distinctly jointed to the stem; and when the leaf falls, it leaves a more or less extensive well-defined scar upon the stem, called the *cicatrix*: in woody Dicotyledons there is generally a little protuberance under the cicatrix, which is termed the *pulvinus*. In Monocotyledons the cicatrix is usually very broad, from the base of the petiole embracing the stem widely. In some cases the petiole is not regularly disarticulated, but withers down; but then the decay generally terminates at a definite point a little above the base, leaving a portion of the latter in the form of a scale-like or tooth-like process projecting from the stem.

Tooth-like processes left by the decay of the petioles may be seen on the underground stem of the common Primrose &c., and on the trunks of certain Palms.

78. The *stipules* or leaf-like appendages of the petiole usually stand at the base of the petiole, one on each side, free or adherent to it (fig. 56). The *free* leafy stipules are sometimes highly developed, and in *Lathyrus Aphaca* they exercise the functions of the blade, the leaves of this plant consisting merely of a petiole destitute of a lamina. When the margins of the stipules next the petiole are continuous with that organ, forming as it were wings to it (*Rosa*), they are called *adnate* (fig. 57). They are also often united by their margins independently of the petiole, or, in other words, are not sepa-

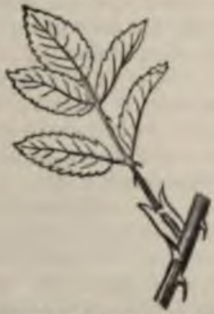
Fig. 56.



Leaf of *Lotus* with free stipules.

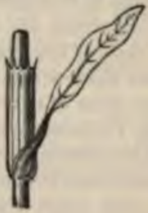
rated from each other (*connate*): thus in the Plane tree and in *Astragalus* they are united by the outer margins (turned away from the petiole) so as to form a kind of leaflet on the opposite side of the stem (*intrapetiolar*); in *Potamogeton* they are united by their inner margins *over* the petiole, so as to form a compound *axillary* stipule; in the Polygonaceæ they are not only united on this side, but also by their outer margins on the other side of the stem, thus forming a short tubular sheath round the latter, called an *ocrea* (fig. 58). All the above cases relate to stipules of single leaves; but similar coherence or lack of disunion occurs in the stipules of opposite leaves, where it is not uncommon to find the two stipules which stand between the leaves, at back and front, more or less confluent into a single leaf-like or scale-like body (*interpetiolar stipule*), so as to form a kind of whorl with the true leaves.

Fig. 57.



Compound (pinnate) leaf of the Rose, with adnate stipules.

Fig. 58.



Ocrea of *Polygonum*.

This interpetiolar confluence of the stipules is very characteristic of the Order Rubiaceæ; and the apparent whorls of the *Stellatæ* (*Galium*, &c.) often exhibit a confluence of the highly developed leaf-like stipules.

79. At the summit of the sheath of the leaf of Grasses exists a little membranous scale, connecting the blade with the epidermis of the stem; it is either entire or forked at the top (figs. 52 & 53); this structure, called the *ligule*, is a mere excrescence from the stalk.

The stipules of some plants fall off at an early period. This is the case with the interpetiolar stipules of various Rubiaceous plants. It also occurs commonly when the stipules form envelopes of the leaf-buds, as in Magnoliaceæ, *Ficus elastica*, the Beech tree, &c.

80. Small secondary stipules exist at the base of the partial petioles of some compound leaves, especially of Leguminosæ (*Desmodium*); they are called stipels (*stipellæ*).

81. For convenience of description the stipule has been here treated as if it were uniformly of the same nature, varying only in form, position, &c. In point of fact, however, the morphological nature of the stipules varies in different plants: sometimes they represent mere excrescences from the petiole; at other times they consist of the lower leaflets of a compound leaf (*Lathyrus*), or they may be leaves formed on a contracted and rudimentary axillary branch.

82. The *lamina* or *blade* (fig. 47 *b*) of the leaf constitutes the most important part of the structure, and exhibits the greatest variety in its forms, which latter require to be studied in detail, as they often furnish the principal characters for the discrimination of species of Flowering Plants and Ferns. It is ordinarily a flat plate, possessing an *upper* and *lower surface*, turned respectively towards the sky and the earth, two *margins*, a *base*, and a *summit*.

In plants of succulent habit the thickness of the leaves is often so great that the sides are as broad as the surfaces, or they are more or less confounded in a *cylindrical*, *prismatic*, or some similar form (*Mesembryanthemum*); and similar external forms are presented by the cylindrical or flattened fistular leaves of the Onion &c.

83. If the blade stands alone upon an undivided petiole, or is sessile on the stem, it is called *simple* (fig. 48). Where the petiole is branched, and bears more than one distinct blade, the leaf is *compound* (fig. 57), and its separate blades are called *leaflets*. Both simple leaves and leaflets may be *entire*—that is, the blade may be undivided at its margins; or it may be more or less deeply incised or lobed.

84. The general form of simple and compound leaves, and the character of the subdivisions of the blade of simple leaves and of leaflets, are associated with the plan of arrangement of the skeleton of the leaf. The solid framework of leaves is composed of woody structures which when large are usually termed *ribs* (*costæ*), the small divisions being called indifferently *nerves* or *veins*. The plan of arrangement of the framework is called the *venation*; the ordinary custom is to call the principal ribs *nerves*, and the smaller branches *veins*. When a distinct principal rib, continuous with the petiole, exists, it is called the *midrib*.

The superabundance of terms is an inconvenience here as in many other departments of Botany. Where it is necessary to select, it is advisable to choose those terms which are least objectionable as not involving hypothetical notions of function; but the term *nerve* may be regarded as figurative.

85. The modes of nervature of leaves may be classed under four principal heads:—

1. *Straight-* or *parallel-nerved* (*folia parallelinervia*), when (with or without a midrib) the principal ribs run in more or less parallel lines from the base to the summit (fig. 59).

2. *Curvinerved* (*f. curvinervia*), when the principal ribs run in curves from the base to the summit (fig. 60), or from the midrib to the margin (fig. 61)—differing little from the foregoing, but occurring in broader leaves.
3. *Palminerved* (*f. palminervia*), when the principal ribs radiate from a point at the base of the leaf (fig. 62).
4. *Penninerved* (*f. penninervia*), when the strong midrib gives off the side-ribs at a more or less acute angle, like the blades on the shaft of a feather (figs. 61 & 63).

The term *triple-nerved* (*triplinervia*) is sometimes used for a modification of No. 4, approaching to No. 3, when the midrib gives off on each side near the base a strong side-rib, which runs up within the margin towards the summit. *Feather-ribbed* (*penninerved*) and *hand-ribbed* (*palminerved*) leaves are most common among the Dicotyledons, but they occur also in many Monocotyledons,—the former, for example, in most Palms, Musaceæ, Zingiberaceæ (fig. 61), &c.; the latter in the Fan-palm, Smilaceæ and Dioscoreaceæ, &c., where there is a transition to the *curved-ribbed* condition (fig. 60), which, with the *straight-ribbed* (fig. 59), is most common in the Monocotyledons. *Straight-ribbed* leaves occur not unfrequently in Dicotyledons, as in *Lathyrus* &c. The most important distinction in the ribbing of the two groups is, that in Dicotyledons the main rib or ribs branch repeatedly at more or less acute angles, and anastomose by their slender twigs, so as to form a netted or reticular framework; while in Monocotyledons the branches passing from the main ribs go off nearly at right angles, become suddenly much more slender, and form a kind of square *latticed* or *cancellate* framework when they are strongly developed (fig. 69).

Fig. 59.

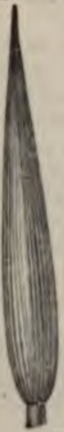


Fig. 60.

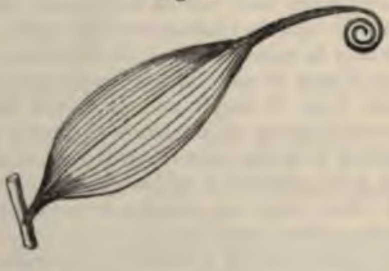


Fig. 61.

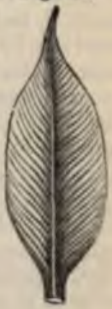
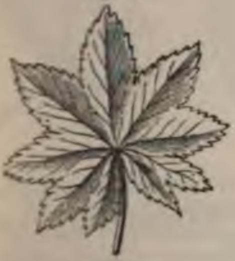


Fig. 59. A parallel-nerved leaf.
Fig. 60. A curvinerved leaf of *Gloriosa superba*, terminating in a tendril.
Fig. 61. A penninerved leaf of *Canna*, with curved secondary nerves.

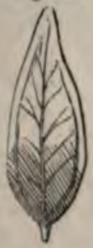
86. The general outline of leaves or leaflets is indicated by certain technical terms, such as:—*circular* or *orbicular* (*Hydrocotyle*, *Tropæolum majus*) (fig. 80); *roundish* or *subrotund*, approaching the foregoing (fig. 64); *elliptical* (fig. 65); *ovate*, egg-shaped with the broad end nearest to the stalk (fig. 66); *obovate*, the same shape, with the narrow end nearest to the stalk (fig. 67); *lanceolate* or lance-shaped (fig. 68); *sagittate* or arrow-shaped (fig. 69); *hastate* or dart-shaped (fig. 70); *cordate*, the shape of a heart on playing-cards, with the broad end nearest to the stalk (fig. 71); *obcordate*, the same shape, with the point attached to the stalk (fig. 101); *reniform* or kidney-shaped (fig. 72); *rhomboidal*; *triangular*; or the reverse of this, *cuneate* or wedge-shaped (fig. 81); *deltoid*; *spathulate* or spatula-shaped (fig. 73); *ensiform* or sword-shaped (as in the Garden-flag); *linear*, a long narrow form with parallel margins (fig. 74); *subulate*

Fig. 62.



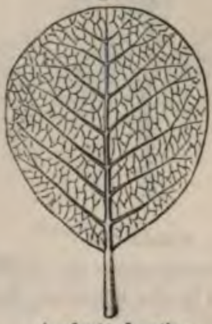
A palminerved serrate leaf.

Fig. 63.



A penninerved entire leaf.

Fig. 64.



A subrotund, entire, penninerved leaf.

Fig. 65.

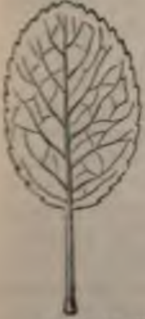


Fig. 66.

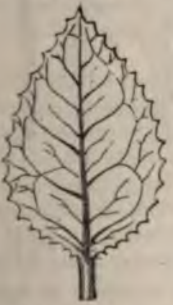


Fig. 67.

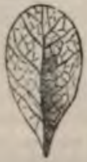


Fig. 68.

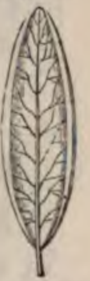


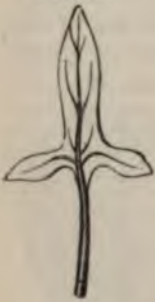
Fig. 65. An elliptical serrate leaf.
Fig. 66. An ovate, acute, and dentate leaf.

Fig. 67. An obovate entire leaf.
Fig. 68. A lanceolate leaf.

or awl-shaped, a slender, short linear form soon ending in a point (fig. 75); *acerose*, needle-shaped and rigid (Pines, Juniper, &c.).

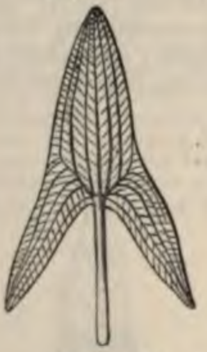
87. Sometimes the forms are intermediate between some of the foregoing, in which case two of the terms are combined, such as *ovate-lanceolate*, signifying a leaf broader than *lanceolate*, and with the lower half wider, as in ovate; *linear-lanceolate*, a long and narrow lance-shaped blade, and so on. The term *oblique* is applied to leaves where the portions on either side of the midrib are unequal, as in the Begonias, Lime, Elm, &c. (fig. 76).

Fig. 70.



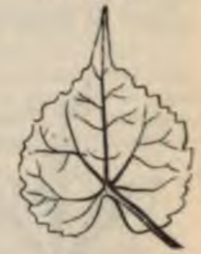
A hastate leaf.

Fig. 69.



A sagittate leaf.

Fig. 71.



A cordate and cuspidate leaf.

Fig. 72.

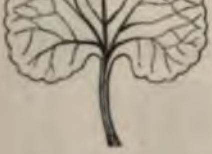
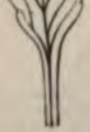


Fig. 73.



Figs. 74, 75.

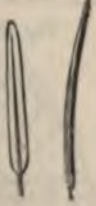


Fig. 76.

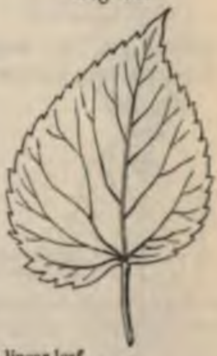
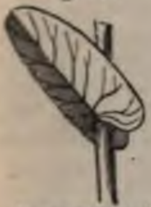


Fig. 72. A reniform crenate leaf.
Fig. 73. A spathulate leaf.
Fig. 74. A linear leaf.
Fig. 75. A subulate leaf.
Fig. 76. An obliquely cordate, serrate, and acuminate leaf.

88. Special terms are also required to describe the character of the base of the leaf. Thus, *cordate at the base* may be added to *ovate*, *elliptical*, or other form, where this condition exists; if a *sessile* leaf

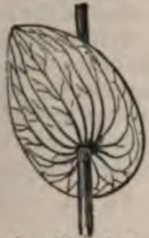
has a cordate base, it becomes *auriculate* or *eared* (fig. 77) when the borders are free, *amplexicaul* or *clasping* if they adhere to the stem. The last form is a transition to the *decurrent* state (§ 76). When the posterior lobes of a sessile leaf extend round the stem completely and become confluent on the other side, the stem appears to *run through* the leaf, and the leaves are called *perfoliate* (fig. 78); when the basilar lobes of a pair of opposite leaves cohere on each side, so as to produce a similar condition, the leaves are termed *connate* (fig. 79). Sometimes the blade is gradually narrowed towards the petiole, and becomes *attenuated* at the base; when the blade passes still more gradually into a broad-winged stalk, a *spathulate* form results.

Fig. 77.



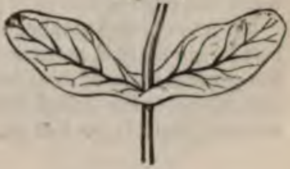
An auriculate leaf.

Fig. 78.



A perfoliate leaf.

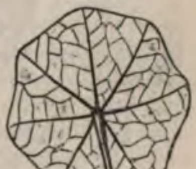
Fig. 79.



Connate leaves.

89. Another character relating to the base is the mode of attachment of the blade to the petiole. Usually the midrib, or set of primary ribs of the blade, is in a direct line with the petiole; but sometimes the ribs, as they pass from the petiole into the blade, separate and radiate from the top of the stalk, so that the latter appears to be inserted into the *back* of the leaf; such a condition is called *peltate*, and occurs in *Nelumbium*, *Tropæolum majus*, and other plants with *orbicular* leaves (fig. 80).

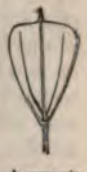
Fig. 80.



A peltate leaf.

90. The *apex* or point of the leaf has certain characters: it may be *acute*, or sharp (fig. 66); *acuminate*, or with the point rather drawn out (fig. 76); *cuspidate*, with a more produced, slender, sharp summit (fig. 71); or *mucronate*, when it is tipped with a *spine* (fig. 81). It may also be *obtuse*, when an ordinarily pointed form is suddenly rounded off at the tip; *emarginate*, when there is a shallow notch where the point should be; *retuse*, when a notch of this kind is deep: this last form approaches to the *obcordate* (fig. 101).

Fig. 81.



A cuneate and mucronate leaf.

91. The *margins* of the leaf are either *entire*, that is, with

an unbroken edge (fig. 64); *crenate*, when they exhibit a series of small rounded teeth or scallops (fig. 72); *dentate*, when the teeth are acute and pointed radially (fig. 66); *serrate*, when sharp teeth point towards the apex (fig. 76); *retroserrate*, when sharp teeth point towards the base. If there are coarse teeth, the margins of which are again more finely toothed, as in the Elm, the leaves are *doubly serrate* (or *doubly dentate*). Sometimes it is requisite to say, *irregularly toothed*, or *incised*, as in many Thistles; and these teeth, as well as those of regularly dentate or serrate leaves, may be tipped with spines, when they are termed *spinose-serrate*, &c. When the outline exhibits shallow wavy curves, it is sometimes called *repand* (figs. 79 & 80). The margin may also be *revolute*, or rolled back toward the lower face (fig. 68). Sometimes, through excessive growth of the marginal parenchyma, the edges of the leaf are *undulated* (as when the edge of a strip of paper swells from being wetted (fig. 88).

92. A very large number of simple leaves, and of leaflets of compound leaves, are divided more deeply between the principal ribs; to such the general name of *lobed* leaves is often applied, and the more or less distinct parts are called lobes; thus we may have *bilobed* (fig. 82), *trilobed* (fig. 83), and so on, according to the number of the divisions.

Fig. 82.

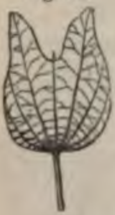


Fig. 83.

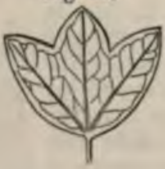


Fig. 84.

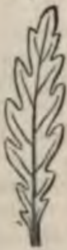


Fig. 85.

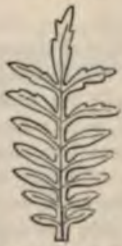


Fig. 86.

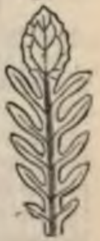


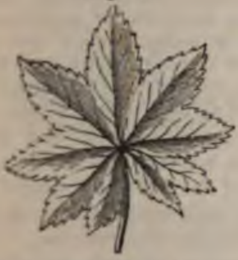
Fig. 82. A bilobed leaf.
Fig. 83. A trilobed leaf.
Fig. 84. A pinnatifid leaf.
Fig. 85. A pinnatipartite leaf.
Fig. 86. A lyrate leaf.

93. But it is found requisite in Descriptive Botany to subdivide lobed leaves into more definite classes; of these there are two principal types, defined by the character of the *ribbing*. When the ribs are arranged on the feathered plan, we first take the prefix *pinnati-* (*feathered*), and subjoin to this a word indicating the degree or kind of division, thus: *pinnatifid* (*feather-cleft*), if the broad notches between the lobes extend from the margin to about halfway between this and the midrib (fig. 84); *pinnatipartite*, if the notches extend nearly to the midrib (fig. 85); *pinnatisect*, if the separate lobes are almost free, and merely connected by a narrow strip of parenchyma. Certain less frequent modifications of these forms

of the feathered type are conveniently distinguished by technical terms, such as:—*sinuate*, a form either of the *pinnatifid* or *pinnatisect* leaf, when the excavations and the apices of the lobes are rounded, as in the common Oak-leaf; *lyrate*, a pinnatifid or pinnatipartite leaf, with the end lobe much larger than the rest (fig. 86); *runcinate*, a *lyrate* or simply *pinnatifid* leaf with the points of the lateral lobes turned towards the base, as in the Dandelion. When the incisions are deep, but very irregular in size and form, the term *laciniate* is sometimes employed.

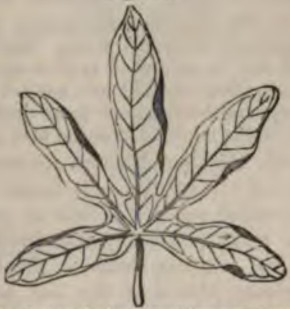
When the ribs have the palmate arrangement, similar terms are subjoined to the prefix *palmi-* or *palmati-*, as *palmifid* (fig. 87), *palmisect* (fig. 89), and *palmipartite* (fig. 88), according to the depth of the divisions. A special modification of this type occurs not unfrequently, when the lower or outer ribs, and consequently the basilar lobes, turn back more or less towards the petiole: such leaves are generally deeply cut; but the general prefix *pedati-* may be used in the words *pedatifid*, *pedatisect*, or *pedatipartite* (fig. 90), according to the rule given above.

Fig. 87.



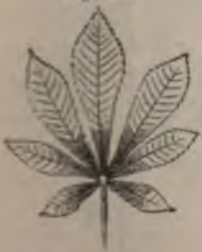
A palmifid leaf.

Fig. 88.



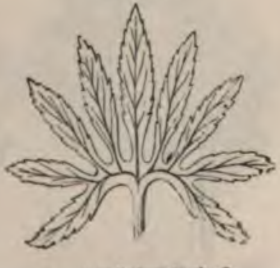
A palmipartite leaf, the lobes undulated.

Fig. 89.



A palmisect leaf.

Fig. 90.



A pedatipartite leaf.

The *bilobed, trilobed, quinquelobed*, and similar forms are usually referable to the palmate type, and should be more definitely named if they occur in a genus where the leaves exhibit many of these forms in a *constant* manner; if the leaves are inconstant in the depth of the divisions, these more general names are preferable.

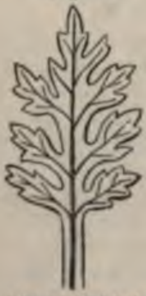
94. Simple leaves divided on the feathered plan exhibit also more complicated conditions. The primary lobes of a pinnately cut leaf may be subdivided again in the same manner, and the secondary lobes again into tertiary lobes. These are named on the same principles, *bipinnati-* or *tripinnati-* *-fid*, *-sect*, or *-partite*, according to the degree of division of the *last set of lobes, i. e.* of the secondary lobes of bipinnatifid (fig. 91) and the tertiary of tripinnatifid. When the leaves are subdivided a *fourth time*, or even where *tripinnatisect leaves have filiform segments*, the term *dissected* is usually employed.

In the foregoing paragraphs we have endeavoured to exclude those numerous technical terms which are either indefinite or superfluous, and may be relegated to glossaries. It must be borne in mind that the terms above defined are applied in a similar manner to the leaflets of compound leaves, next to be described, being subjoined in description to the terms which define the plan and degree of division of the petiole.

95. Compound leaves are such as have the petiole branched once or more times before it bears blades; the branches of the petiole are called *partial petioles* or *petiolules*, and are often articulated to the main petiole, which in this case is occasionally termed the *rachis*. Stipels occur at the bases of some partial petioles. The separate blades of the leaf are called *leaflets* (*foliola*), or *pinnæ*. Compound leaves may be classed generally into simply, doubly, triply compound or decompound (*supradecomposita*), according to the number of successive branchings of the petiole. The ramification follows the same types as that of the ribs of simple leaves, and exhibits analogous subordinate modifications.

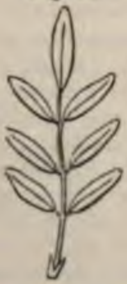
*Pinnate* leaves are such as have a rachis bearing sessile or stalked

Fig. 91.



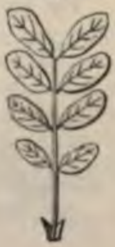
A bipinnatifid leaf.

Fig. 92.



An imparipinnate leaf.

Fig. 93.



A paripinnate leaf.

lateral leaflets arranged on the feathered plan. Sometimes there is an odd terminal leaflet, when the leaf is *unequally* or *impari-pinnate* (fig. 92). When there is no end leaflet, the leaf is *abruptly* or *pari-pinnate* (fig. 93). *Interruptedly pinnate* means that the opposite pairs of leaflets are alternately large and small, as in *Agrimonia*. The pairs of leaflets are sometimes called *juga*, and if only one pair exists, the leaf is *unijugate* (fig. 94); if more pairs, *multijugate*. If

Fig. 94.

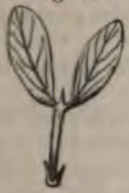


Fig 96.

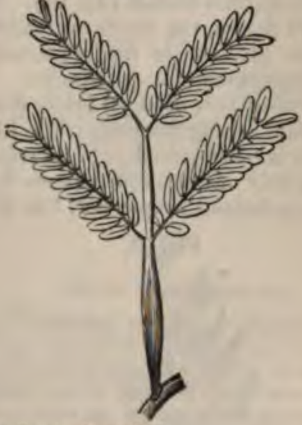


Fig. 95.

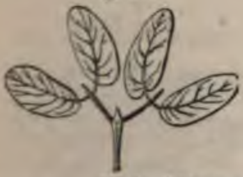
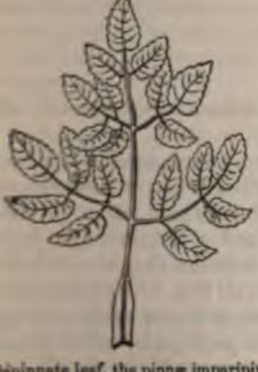


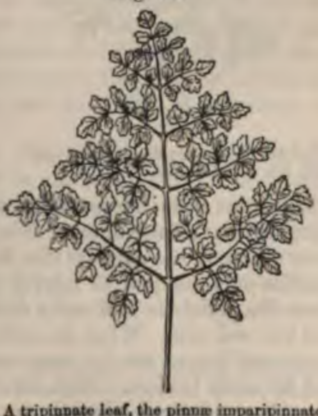
Fig. 94. A binate, geminate, or unijugate pinnate leaf.
Fig. 95. A bipinnate leaf, the pinnæ unijugate.
Fig. 96. A bipinnate leaf, the multijugate pinnæ paripinnate.

Fig. 97.



A bipinnate leaf, the pinnæ imparipinnate.

Fig. 98.



A tripinnate leaf, the pinnæ imparipinnate.

the leaflets are not in pairs, but alternate with each other, the leaf is *alternipinnate.*

*Bipinnate leaves* are formed when the main petiole bears secondary petioles with distinct leaflets pinnately arranged (figs. 95–97). *Tripinnate* leaves exhibit an additional (tertiary) series of partial petioles with distinct leaflets (fig. 98). When the division goes beyond the third degree, the leaves are called *decompound* (fig. 99); but it is more common to find bipinnate or tripinnate leaves with their leaflets pinnatifid, -partite, &c.

*Palmate* (or *digitate*) leaves are such as have a number of distinct leaflets arising from one point, like the ribs of a simple leaf when the plan is palminerved. *Bi-* or *tripalmate* leaves probably do not exist. The only modification appears to be the *pedate* leaf, analogous to the pedatisect simple leaf, but with distinct leaflets (fig. 100).

Fig. 99.

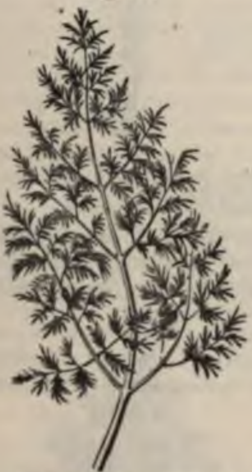


Fig. 100.

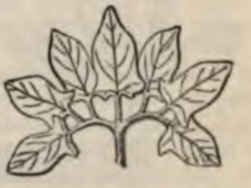


Fig. 101.

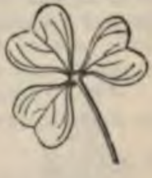


Fig. 99. A pinnately decompound leaf.
Fig. 100. A pedate leaf.
Fig. 101. A ternate leaf with obcordate leaflets.

The terms *ternate*, *quinate*, and *septenate* are often applied to palmate leaves with a definite number of leaflets. *Ternate* leaves, however, may occur either on the palmate (fig. 101) or pinnate plan; if on the latter, there is only one pair of lateral leaflets and a terminal one, but in these the petiole is ordinarily developed between the pair of leaflets and the end one. What are called *biternate* (fig. 102) and *triternate* compound leaves are in most cases *pinnate* leaves with unijugate and terminal leaflets. Such leaves should perhaps be called *ternato-pinnate* or *biternato-pinnate*, &c.

A modified form, apparently intermediate between *pinnate* and *palmate* leaves, like some *ternate* leaves, occurs through the suppression of the main rachis of the bipinnate leaves of some Acacias, giving what may be called a *palmipinnate* form (fig. 103).

Fig. 102.

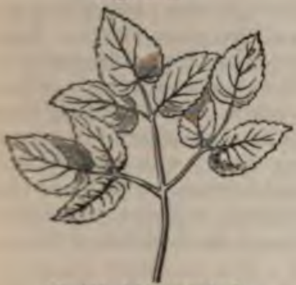


Fig. 102. A biternate leaf.

Fig. 103.

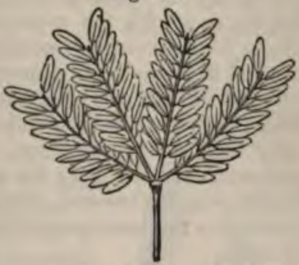


Fig. 103. A palmipinnate leaf.

The leaflets of compound leaves of Flowering plants are ordinarily called *pinnæ*, and their subdivisions *lobes*; but in the Ferns, where the leaves are highly compound, and the segments somewhat variable in the degree of confluence, the primary divisions of the leaf are called *pinnæ*, the secondary *pinnules*, and the tertiary *lobes* or *segments*. In highly compound leaves, the ramification of the petiole and subdivision of the laminar structure become less complex toward the apex.

96. The varieties of *texture* of ordinary leaves depend chiefly upon their anatomical condition; but it is requisite to notice here several terms, such as *membranous*, *leathery* (or *coriaceous*), *succulent*, &c., used in Descriptive Botany, but which scarcely require explanation. In aquatic plants the leaves are usually of slighter texture: when they *float* on water (*natant leaves*) the forms and general external characters are not much modified; but when they grow wholly under water (*submerged leaves*), they are not only more delicate, but are sometimes cut up into fine filiform segments, as in *Ranunculus aquatilis*.

97. The *duration* is different in different plants. Those which are unfolded in spring and fall off in autumn are called *deciduous*. What are called *evergreen* leaves vary in duration: thus in ordinary evergreens, such as Ivy, Cherry-laurel (*Prunus Laurocerasus*), &c., the leaves remain through the winter and fall off only when the new ones are becoming developed in the spring; while in many Conifers, as in species of *Pinus*, *Araucaria*, &c., the leaves remain attached for many years.

The anatomical structure of leaves exhibits many interesting modifications, related in some degree to the media and climates in which plants grow. These will be more particularly explained in another place.

98. The *surfaces* of leaves, like those of herbaceous stems, exhibit a variety of conditions dependent on the character of the epidermal layer. The term *glabrous* indicates a smooth surface without hairs or other appendages; *glabrescent* is used to signify that a surface, hairy when young, becomes smooth when the leaf is mature, by the hairs falling off. Some smooth surfaces are *shining*; and this is very often the case with the upper surface of evergreen leaves. Hairy surfaces are differently denominated, according to the character of the hairs and their mode of occurrence. Thus a *pilose* surface is covered with scattered soft and small hairs, a *hirsute* with scattered long hairs, a *hispid* with scattered stiff hairs; while a *pubescent* surface is covered closely with short soft hairs, a *villous* closely with longish weak hairs; and when the hairs are curled and interwoven, the terms *silky* (*sericeus*), *woolly* (*lanatus*), *felted* (*tomentosus*), or *floccose*, are applied, according to the coarseness of the hairs and the thickness of the coat they form.

99. What may be called the natural smoothness of surfaces may be interfered with by other irregularities analogous in their nature to hairs. Slight, almost invisible rigid projections render the surface *scabrous*; hard rigid hair-like processes, called *bristles* or *setæ*, make the surface *setose*; and similar structures still more developed (occurring mostly at the apex and the points of the teeth of leaves), called *spines*, sometimes occur and produce a *spinous* surface. Modified, usually compound hairs, containing oily or resinous secretions, are called *glandular* hairs, rendering a surface *viscous* or *glutinous*, which conditions, however, are sometimes produced by *glands* sunk in the epidermis. *Stings* are long stiffish hairs containing an irritating fluid. *Scaly* (*lepidotus*) surfaces are produced by the occurrence of minute *stalked* flat scales, analogous in their nature to hairs. Sometimes the cuticular layer of the leaf separates in minute scale-like fragments, giving a *scurfy* appearance to the surface, which is termed *furfuraceous* (as in the leaves of the Pine-apple and its allies). The *pruinose* condition is that which results from the conversion of the cuticle into a thin detachable film of waxy matter, of which the "bloom" of plums, grapes, &c. affords an example.

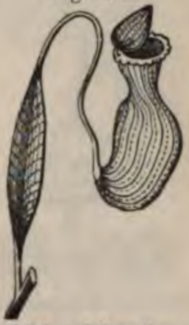
### *Special Modifications of the Leaf and its Parts.*

100. Under the head of the petiole we have spoken of *phyllodia* as blade-like forms of the petiole (figs. 50 & 51). Not only does the leaf-stalk exhibit this and other modifications, disguising its real nature, but the blade also and the stipules are subject to similar modifications, in which the organ or region is only recognizable by its position and relations.

As these metamorphic structures fall under certain types, which are represented in different cases by all the different regions of the leaf, it is most convenient to describe them under special names.

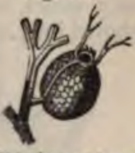
101. *Pitchers* (*ascidia*) are structures of the form indicated by their name, produced by peculiar modes of development of the petiole, the blade, or of both together. One of the best-known examples is found in the *Nepenthes*, or Pitcher-plants, in which a portion of the leaves exhibit a very long stalk, winged at the base, supporting at its extremity a pitcher-like sac of ordinary leafy texture, furnished at its mouth with a little flat plate resembling a lid (fig. 104). The pitcher is commonly explained as a kind of *phyllode*, or foliaceous petiole, rolled up, and with its margins confluent, the lid-like body being regarded as the *lamina*; but it appears more correct to consider the pitcher as the lamina furnished with a distinct terminal lobe (*operculum*). *Sarracenia*, a North-American bog-plant, has analogous pitchers, which are sessile at the base of the flowering stem; *Heliamphora* (Guiana) has the pitchers less complete, the inner side being slit down as it were for some distance, from the imperfect confluence of the margins of the leaf. In *Dischidia Rafflesiana* the pitchers are plainly formed from the blade, and are open at the end next the petiole; and a similar condition exists in the pitchers formed from the bracts of *Marcgraavia* and *Norantea*. Somewhat allied to the above, on a small scale, are the *utriculi*, or sacs of the *Utriculariæ* (fig. 105), little bladder-like organs, closed at first by a lid, developed from some of the lobes of the compound leaves of these aquatic plants, and apparently serving as "floats." In other aquatics (*Trapa*, *Pontederia*, &c.) floats are formed by *inflated petioles*, constituting as it were indehiscent pitchers, surmounted by ordinary blades.

Fig. 104.



Pitcher of *Nepenthes*.

Fig. 105.



Utriculus or air-sac of *Utricularia*.

Teratological illustrations of the origin of pitchers are occasionally afforded by garden plants. This has been especially observed in the Tulip, in which the leaf next the flower-stalk has been found with its margins completely confluent into a kind of spathe, which bursts by a *transverse* fissure to allow the flower to appear.

102. *Tendrils* (*cirri*) are thread-like processes, curled spirally, by which weak-stemmed plants attach themselves to foreign bodies. They may be modifications of any part of the leaf or of a branch. In *Lathyrus* the blade-structure of the leaf is more or less deficient in different species. In *L. Aphaca* (fig. 106) it is wholly wanting,

the petiole running out into a tendril, which may be regarded as consisting either of the leaf-stalk alone, or of this and the midrib of the lamina. In *L. odoratus* (Sweet Pea) the pinnately compound leaf has one pair of leaflets, and usually one pair of tendrils, and a terminal tendril in the ordinary place of the remaining leaflet. In the edible garden Pea there are several pairs of leaflets, and often several pairs of tendrils, with a terminal one. In *Gloriosa superba*, a Liliaceous plant, the broad simple lamina runs out into a terminal tendril (fig. 107). In *Smilax* (fig. 108) the two stipules are represented by a pair of tendrils; while in the Cucurbitaceæ one tendril only occurs, which some regard as a stipule, others as a metamorphosed leaf, others, again, as a branch.

Fig. 106.

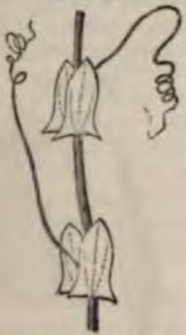


Fig. 107.

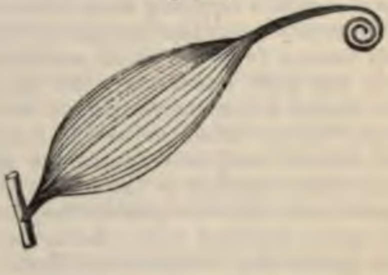


Fig. 106. Leaves of *Lathyrus Aphaca*, represented by tendrils, with large foliaceous stipules.
Fig. 107. Leaf of *Gloriosa superba*, prolonged into a tendril.

Fig. 108.

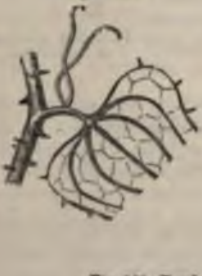


Fig. 109.

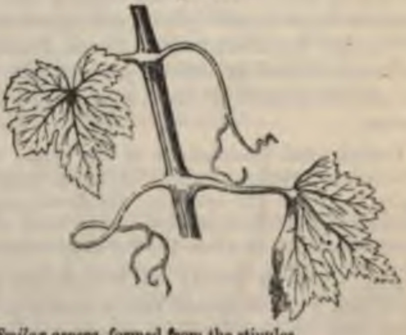
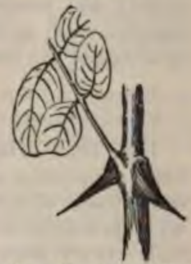


Fig. 108. Tendrils of *Smilax aspera*, formed from the stipules.
Fig. 109. Leaves and tendrils of the Vine.

The tendrils of the Vine (fig. 109) are modified flowering branches, placed opposite to leaves, and often tuberculated by the existence of abortive flower-buds. The nature of the axillary tendrils of Passion-flowers is similar.

Fig. 110.



Base of the leaf of *Robinia*, with stipules developed as spines.

103. *Spines* (*spinæ*) are hard, sharp-pointed woody processes, formed, like tendrils, by modification of entire organs or parts of such. Thus, in the common Berberry some of the leaves are represented by compound spines, in the axils of which arise fasciculate groups of leaves. In the False Acacia-tree (*Robinia Pseudacacia*) the stipules are represented by a pair of spines at the base of the petiole (fig. 110), while in certain species of *Astragalus* the petioles are converted into spines after the fall of their leaflets. Spinous processes are developed upon the petiole in the upper part of the compound leaves of certain Palms (*Plectocomia*).

True spines, however, are more frequently dependencies of the stem, closely associated with the leaves: thus in the Gooseberry they are developed from the *pulvinus*, or protuberance below the base of the petiole. In the Black-thorn (*Prunus spinosa*) the spines are real branches (fig. 111), as also are the spines of *Gleditschia triacanthos* (fig. 112), and the principal spines of Furze (*Ulex*), in which, however, the points of the leaves are spinous also.

Fig. 111.

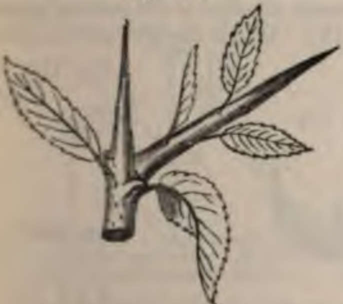


Fig. 112.

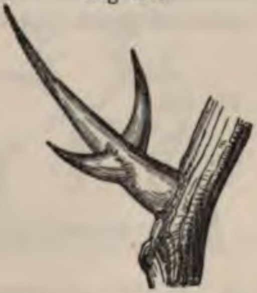


Fig. 111. Spinous branch of *Prunus spinosa* (Black-thorn).
Fig. 112. Spinous branch of *Gleditschia triacanthos*.

104. *Thorns* (*aculei*), properly so called, are sharp woody processes, straight or curved, occurring upon stems, leaf-stalks, at the points or on the margins, or upper surface of leaves. They are distinguished from true spines by their originating from the epidermis, like hairs, glands, &c., and by having no connexion with the internal woody substance of the stem or ribs of the leaves &c.

105. *Glands.*—This is perhaps the most convenient place to mention the nodular or discoid glandular bodies that occur in connexion with certain leaves, as on the petioles of *Passiflora* &c. They are distinct in their nature from the epidermal glands above mentioned (§ 99), and considerable attention has been directed to them on morphological grounds; hence they will be adverted to again in speaking of the flower.

## Sect. 5. THE LEAF-BUD.

106. The bud is a compound structure, composed of a solid conical basis, supporting a number of rudimentary leaves. In the *leaf-bud*, or rudiment of a shoot, the conical base represents the future stem, with its internodes as yet undeveloped; the scales are either entirely rudimentary leaves, or a portion of them on the outside are modified leaf-structures, forming scales for the protection of the inner leaves, and destined to fall off when the bud expands. In the early conditions, the *flower-bud* is essentially analogous to a leaf-bud; but its ultimate history is different, as will be shown hereafter.

Many of the general characters of buds have been described already, under the head of the stem; but there are some other more special peculiarities which require separate treatment here; and repetition of certain more important facts will not be disadvantageous.

107. In all seeds, except in those of the few Orders which present an incomplete or acotyledonous embryo, the young plant is possessed of a rudimentary bud, called the *plumule*, situated at the point of growth of its ascending axis (figs. 113–115). This is the *terminal bud* of the young plant; and stems and shoots only retain the power of elongating so long as they possess such a bud at their extremity. When it is

Fig. 113.

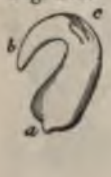


Fig. 114.

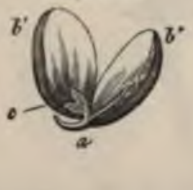


Fig. 115.

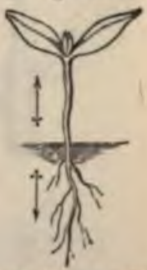


Fig. 113. Monocotyledonous embryo of *Potamogeton*, cut through perpendicularly: *a*, radicle; *b*, cotyledon; *c*, plumule.
Fig. 114. Dicotyledonous embryo of the Bean (*Faba*), with the cotyledons *b' b''* separated: *a*, radicle; *c*, plumule.
Fig. 115. Diagram of a germinating Dicotyledon, with the plumule or terminal bud between the expanded cotyledons.

removed by artificial means, by frost, or, by metamorphosis, is replaced by a flower, the onward growth of the shoot ceases. In the Dicotyledons the power of growth generally becomes early distributed among a number of buds; but in many Monocotyledons the terminal bud retains its original preeminence, becomes very large, and by its continuous evolution produces an unbranched, columnar stem, as in the Palms, &c.

Those Ferns which become arborescent, likewise grow by a single large terminal bud. The Lycopodiaceæ exhibit a curious series of bifurcations, which seem to arise from the suppression of the terminal bud every time ramification is repeated.

108. *Axillary buds* are the origin of the ramification of stems. They are developed in the *axils* of leaves; and as they unfold into secondary axes, they become the terminal buds of such shoots. Other axillary buds are formed at the nodes of these secondary shoots, to repeat the ramification by developing into tertiary axes according to the type of the species.

It is evident from this, that the mode of branching of a stem must be essentially dependent on the arrangement of leaves; but a complication arises from the frequent suppression or non-development of the axillary buds, often according to a regular plan; and, in fact, it is very seldom that all the axillary buds of a stem are developed (figs. 116 & 117).

Fig. 116.

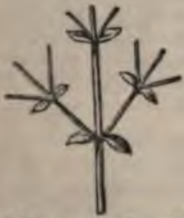


Fig. 117.

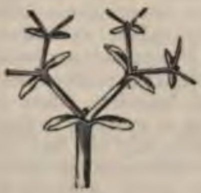


Fig. 116. Indefinite ramification, with development of terminal and axillary buds.
Fig. 117. Definite ramification, with arrest of the terminal and development of the axillary buds, producing bifurcation.

This abortion of axillary buds is most extensively displayed in Monocotyledons; for the frequent existence of dormant buds in the leaf-axils, even of Palms, is shown not only by the occasional production of isolated lateral shoots, but by the frequent, and in some cases constant, development of buds in the axils of the basilar leaves, forming suckers round the base of the stem. A similar phenomenon occurs in the propagation of *bulbs* &c.

Among Dicotyledonous plants, the influence of the suppression of buds in regular order is very great. In the Labiatæ we have opposite leaves; and as pairs of axillary buds are developed, the ramification is generally very symmetrical; in some of the *Caryophyllaceæ* with similarly *decussate* opposite leaves, one axillary bud only is developed, and the other is suppressed at each node, so that the branches, arising one by one, stand spirally arranged upon the stem. In the Firs, the branches often appear to arise in whorls, owing to the periodical development of a number of buds in the axils of closely succeeding spirally arranged leaves, with long intervals of total abortion.

The Ash grows year after year from its terminal bud, which closes up into a winter-bud in the autumn. In the Hazel, Elm, &c., the terminal bud is not developed in the autumn, and the axillary bud next below continues the growth. In the Horse-chestnut (fig. 121), the terminal bud of the annual shoot resolves itself into an inflorescence, and the growth of the next year depends upon the axillary buds; the same is the case in the Lilac (*Syringa vulgaris*) (fig. 118), in which, however, in this country, the terminal bud is generally killed by frost in the winter, and the pair of axillary buds next below produce blossom, causing still more marked bifurcation of the branches.

Fig. 118.

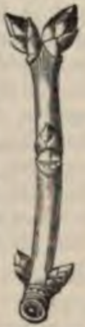


Fig. 118. Shoot of the Lilac, destroyed down to the first pair of axillary buds.

Fig. 119.

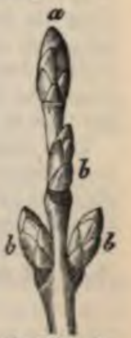
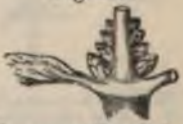


Fig. 119. A shoot, with a terminal (*a*) and solitary axillary buds (*b*, *b*, *b*).

As a general rule, of course, the frequent suppression or conversion into blossom of terminal buds tends to produce a bushy mode of growth, and *vice versâ*. In addition to this, the relative *force* of development of terminal and axillary buds is very important in determining general form, as we see in comparing the Black Poplar with its common tall variety (the Lombardy Poplar), or Coniferous trees generally with deciduous trees. Even among the individuals of the same species we observe great differences in this respect, dependent on external conditions; for both Dicotyledonous trees and Conifers differ much in the relative proportion of main trunk and branches, when grown in close plantations, or standing in open situations.

Ordinarily, only one bud exists in an axil (fig. 119); but frequent exceptions to this occur, as in some species of Maple, in Honeysuckles (fig. 120), and in the Walnut. However, one of these is generally much larger than the rest, and is called the *principal* bud, while the others are *accessory*.

Fig. 120.



Numerous axillary buds of *Lonicera*.

In the family of Solanaceæ the axillary buds often occur in an irregular position, arising from the stem at a little distance above empty leaf-axils. This is supposed to be due to the cohesion of the stalk of the bud with the stem.

109. *Adventitious* or *accidental* buds are those which appear, contrary to the usual order, at indefinite points, unconnected with the axils of leaves. Generally speaking they are abnormal products, presenting themselves under special conditions. They usually occur

on organs in a very active state of vitality, subjected to stimulating external conditions, especially where, through natural or artificial operations, there is an absence or insufficiency of normal buds to carry off the developmental energy of the plant or organ.

Adventitious buds may be produced from any part of the plant. With regard to those produced on old stems, as in pollarded trees, or those which occur on subterraneous stolons, as in the Rose, Ash, &c., it is not always easy to decide without dissection whether the buds are really adventitious or merely latent axillary buds stimulated into development; but true adventitious buds do occur. The production of adventitious buds on true roots has been frequently observed, as in *Pyrus japonica*, *Maclura aurantiaca*, *Paulownia imperialis*, &c.; and the *Anemone japonica* is commonly propagated by cuttings of the root. The formation of adventitious buds on leaves is a still more remarkable physiological phenomenon. It has been observed chiefly in succulent leaves, but is not exclusively confined to them. When it takes place, the first sign of development is the production of adventitious roots, followed by the formation of a cellular nodule which subsequently assumes the character of a bud. Among natural examples, the leaves of *Cardamine pratensis* have been observed to form adventitious roots on the lower side when lying upon wet ground, and even to produce buds; the leaves of several Ferns, such as *Woodwardia radicans*, root at the end, and produce buds which propagate the plant; and many similar instances might be cited. Artificial production of buds on leaves is now a familiar fact, under the influence of heat and moisture, not only on the scales of bulbs, but on the green leaves or even fragments of the leaves of *Bryophyllum*, *Echeveria*, *Gloxinia*, *Gesnera*, *Hoya*, &c.; the *Orange* and the *Aucuba japonica* may also be propagated by their leaves. Sometimes the leaves produce rootlets alone, and remain stationary there, without having force enough to develope a bud.

The formation of adventitious buds on leaves, especially in *Bryophyllum*, where a number are often produced, arranged on the margin, is of great interest in connexion with the theories of the structure of ovaries and the origin of their ovules.

110. The bud which continues the growth from the plumule of a germinating plant (fig. 115), and the axillary buds produced during a season of active growth, are composed of rudimentary leaves; but the winter- or resting buds formed on most deciduous trees and shrubs of temperate climates present the peculiarly modified foliar organs called *bud-scales* (*tegmenta*), analogous to the scales of bulbs and other subterraneous buds of herbaceous plants (figs. 121 & 122). Buds without scales are called *naked*. The *scales*, when present, are mostly of leathery or membranous texture, and are often clothed more or less densely with hairs, which are sometimes glandular and produce a resinous or glutinous secretion, which exudes when the buds swell.

When winter-buds swell and open, throwing off their scales, the internodes between the latter do not elongate, while those between the nascent leaves do; consequently the starting-point of each annual period of growth of a branch with an indefinitely developed terminal bud is indicated by a little band of scars marking the place where the scales stood.

Fig. 121.

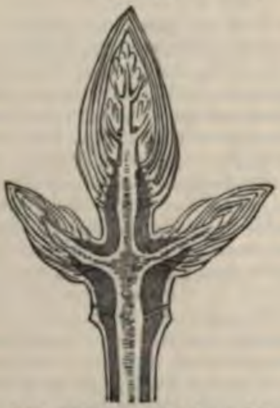


Fig. 122.

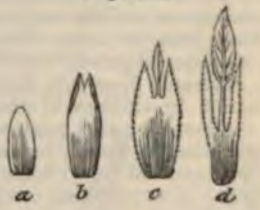


Fig. 121. Section of the end of a shoot of the Horse-chestnut, showing the terminal and two axillary buds; the terminal bud contains an inflorescence, surrounded by scales and rudimentary leaves.
Fig. 122. Bud-scales *a*, *b*, and rudimentary leaves *c*, *d*, from the winter-bud of *Prunus Avium*.

111. The first two scales of a bud usually stand right and left of the axil on which the bud arises; the succeeding scales assume at once the regular character of arrangement of the leaves of the species.

In winter-buds there is commonly a gradual transition from the pure scale to the true leaf (fig. 122), as occurs in bulbs; and the scales, as in bulbs, are referable chiefly to the vaginal or petiolar portion of the leaf. But the scales originate differently in different cases: thus we have *petiolar scales*, as in the Walnut and Horse-chestnut; *stipular scales*, as in the Vine, Oaks, Elm, Poplars, &c.; in this case, however, especially in the outer scales, the stipules and the petiole are confluent into one organ (*Prunus*, *Rosa*, &c.) (fig. 122). *Foliaceous scales* are formed by the blade of the leaf, of which we have examples in the Lilac, Maples, Coniferæ, &c.

112. The mode in which rudimentary leaves are arranged in leaf-buds is called the *vernation*, and furnishes important systematic characters. Two points have to be regarded here, viz.:—1, the arrangement of the leaves in relation to each other; and, 2, the manner in which each separate leaf is folded. The general arrangement is called *imbricate* or *valvate*, according as the margins of the leaves overlap one another or simply meet without overlapping; but more minute distinctions are observed, and these depend to a great

extent on the phyllotaxy of the species. Thus with the $\frac{1}{3}$, $\frac{2}{5}$, or other spiral plan, we have usually triquetrous (fig. 124) or quincuncial (fig. 126) *imbricate* buds proper; with alternate $\frac{1}{2}$ or distichous leaves the vernation may be *equitant* (fig. 123), where each leaf, sharply folded (*conduplicate*), completely embraces its successor (as in the Flag), or *half-equitant* or *obvolute*, where the leaves are similarly folded, but each leaf embraces only one (lateral) half of the blade of its successor. *Valvate* buds occur mostly where the leaves are opposite; a modification of this form exists where the margins of the leaves are rolled inwards (fig. 125), and is called *induplicate vernation.*

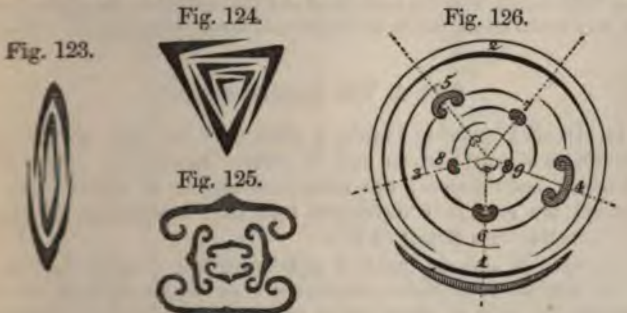


Fig. 123. Fig. 124. Fig. 125. Fig. 126.

Sections of Buds showing vernation.
Fig. 123. Imbricated, and equitant (of a Grass).
Fig. 124. Imbricated, triquetrous (of a Carex).
Fig. 125. Induplicate, decussate (of the Apple).
Fig. 126. Imbricated, quincuncial (of a Poplar).

113. The individual leaves in a bud are either *flat, folded,* or *rolled*. For the first, of course, no special term is requisite. Of the folded leaves we have:—*reclinate*, or inflexed, where the leaf is folded horizontally, so that the point is brought down to the base (*Liriodendron*); *conduplicate* (fig. 123), where the leaf is folded perpendicularly at the midrib and the lateral halves are placed face to face (Oak); and *plicate* (fig. 127), where the blade exhibits several perpendicular folds, as in a fan (Vine, Beech, Maple, Currant, &c.); this last is often combined with the preceding. When rolled up, also, this may take place in either direction: where the apex of the leaf is rolled down toward the base, as in the Ferns and in the flower-stalk of *Drosera*, it is *circinate*; if the leaf is rolled up from

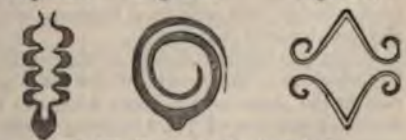


Fig. 127. Fig. 128. Fig. 129.

Fig. 127. Vernation of a plicate leaf.
Fig. 128. Vernation of a convolute leaf.
Fig. 129. Vernation of revolute leaves.

side to side like a plan, with only one edge free, as in the Cherry &c., it is *convolute* (fig. 128); when both margins are rolled inward toward the midrib, it is *involute* (fig. 125); and when both margins are rolled outward toward the midrib, it is *revolute* (fig. 129).

All these terms, both the individual and the collective, are applied in the same way to the arrangement of the parts of flower-buds, called *æstivation*.

## Sect. 6. THE INFLORESCENCE.

114. In all Flowering Plants, a portion of the buds change their character at certain periods and in certain situations. They cease to produce leafy shoots; the foliaceous organs of which they are composed are gradually developed into that assemblage of organs which constitutes a flower (§ 21).

So intimately are the leaf-bud and flower-bud related, that, under peculiar conditions, producing monstrous growths, flower-buds are seen to expand into tufts of green leaves, or imperfect flowers to throw out leafy shoots from their centres; such cases are often observed, for instance, in cultivated Roses; and leaf-shoots may likewise exhibit more or less of the characteristics of a flower, &c.

115. Flower-buds are subject to the same laws of arrangement as leaf-buds. The buds which commence the growth of the reproductive structures may be at once developed into solitary flowers, or, as is more common, the blossom-buds unfold into a system of branches terminating in flowers, the branches all originating in the axils of modified leaves, called *bracts*. The solitary flower, or the connected system of flowers arising from one point, is called the *inflorescence*, which is either *terminal* (fig. 130) or *axillary* (fig. 131).

The inflorescence is produced from the terminal bud, or from this and one or more of the upper axillary buds in most annual plants; and there is often a gradual transition from the true-leaf stem into the bract-region, or inflorescence. The same is the case, to a great extent, with the flowering stems of biennials. The inflorescence of herbaceous perennials, bulbs, &c. is either terminal or axillary (§§ 46–48), as is that of arborescent plants. In the Horse-chestnut (fig. 121) and Lilac, for example, each terminal bud ends in a blossom, while in the Apple and its allies the inflorescence is axillary.

When the inflorescence is developed from the terminal bud of an unbranched stem, the growth of the plant ends in the blossoming, as is the case in the *Agave* or American Aloe, the Talipot and other Palms, which require a number of years to bring them to the point of flowering, and then die away, like a bulb with a terminal inflorescence, the plant, however, being sometimes propagated at the same time by offsets from the axils of the lower leaves. The inflorescence of other unbranched Palms, such as the Cocoa-nut, is axillary, and thus may be repeated indefinitely.

116. A flower-bud may be either *sessile* or *stalked*; if the latter,

its stalk is called the *peduncle*; in branched forms of inflorescence, the slender stalks of the individual flowers are called *pedicels*.

Fig. 130.

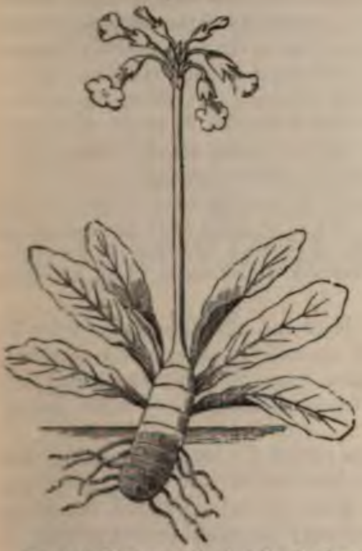


Fig. 131.

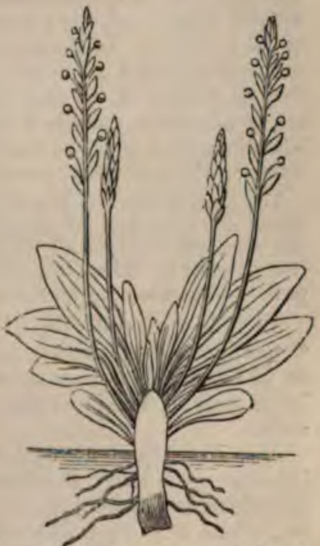


Fig. 130. Diagram of the Cowslip, the flowering stem (scape) arising from a terminal bud.
Fig. 131. Diagram of *Plantago media*, the spiked flowering stems arising from the axils of the leaves.

117. The simplest forms of inflorescence consist of solitary flowers, either terminal, as in the Tulip, or axillary, when simple peduncles arise from the axils of ordinary leaves, as in *Lysimachia Nummularia*, &c.

118. The term *scape* (*scapus*) is applied to a stem devoid of true leaves, arising underground from the terminal bud or from the axil of a scale or leaf of a rhizome, bulb, &c.; this may be *simple*, as in the case of the Tulip, the Primrose, &c., or *compound*, as in the Hyacinth, Cowslip (fig. 130), the Plantain, &c. (fig. 131); it may be called compound also when it terminates in a *capitulum*, as in the Dandelion, Daisy, &c.

When solitary flowers arise in the axils of ordinary leaves, the flower-leaf or bract-region of the stem is scarcely represented; but, generally speaking, those parts of the stem which bear flowers are separated to a certain extent from the true-leaf region, and form a distinct association of parts, representing the bract-region; such is distinctly the case in the compound scapes of the plants above referred to (fig. 131). In the flowering stems of annuals and biennials it is often difficult to draw a line at the boundary of the true-leaf region and the inflorescence, from the leaves passing insensibly into bracts from below upwards, as in the Foxglove.

119. The leaves of the flower-leaf region of the stem are called *bracts*. They are mostly smaller than the leaves preceding them, usually simple, and often scale-like, consisting of the vaginal portion of the leaf only. In the generality of cases they are green; but not unfrequently they are tinged with the same colours as flowers (as in various Sages), or are even entirely petaloid. In other cases they are membranous, and then often very transient in their existence. The diminutive term *bracteole* is applied to the small bracts which occur on the pedicels of certain plants, often in pairs.

The term *bracteole* is loosely applied by some authors to the smaller bracts of a compound inflorescence; but it is much more convenient to use the term *bract* for all leaves which subtend branches of the inflorescence, and to call those scales *bracteoles* which occur on an ultimate pedicel, as in many Leguminosæ.

120. As a general rule, all ramifications of inflorescence arise in the axils of bracts; but the bracts are sometimes regularly abortive, as in the Cruciferæ. On the other hand, we sometimes find the lower part of the inflorescence crowded with bracts with empty axils.

121. In many Monocotyledonous plants the bract subtending the inflorescence is large, and forms a kind of sheath, called a *spathe*. Sometimes this surrounds only one flower, as in the Daffodil, the Flag, &c., where it is of membranous texture; the membranous spathe of the Onion and its allies encloses a dense inflorescence; in the Araceæ (fig. 133) it is still more developed, and sometimes of petaloid structure, as in the so-called Trumpet-lily (*Richardia æthiopica*), where it encloses the club-like inflorescence; while in the Palms (fig. 134) it assumes enormous dimensions and a leaf-like or even fibrous texture, forming a sheath to a large and greatly ramified inflorescence.

122. In other cases, bracts are collected together, forming a whorl or densely packed spire, called an *involucre*. The Umbelliferæ have frequently verticillate involucres at the base of the umbels, and sometimes secondary whorls or *involucels* at the secondary umbels (fig. 140). In the Compositæ also, where the flowers are crowded on a common receptacle, the bracts form an involucre (figs. 141–146), the parts of which are sometimes called *phyllaries*; smaller scale-like bracts occurring among the florets of these capitula are called *paleæ* (figs. 145 & 146). Other examples of involucre are furnished by the *cupules* of the Oak, Beech, Filbert, &c., also by the *glumes* or two outer scales of the spikelets of Grasses.

123. The different forms of the Inflorescence or connected systems of floral axes are divisible into two classes:—1, the *indefinite*, where

the terminal bud of the main or primary axis does not form a flower, the flowers being borne on *secondary lateral* branches; and, 2, the *definite*, where the *primary* axes bear *terminal* flower-buds, while the succeeding flowers spring from secondary axillary branches produced lower down, and subsequently to the terminal bud.

Examples of the first are seen in the Cruciferæ, especially the Wallflower, where a few flowers at first appear in a tuft, while the seed-vessels are afterwards wide apart on an elongated raceme, the uppermost being the youngest. In the Foxglove and similar plants we may produce a very long development of the indefinite structure by picking off the lower flowers as they wither, when, as no seed is formed, the indefinite terminal bud retains its energy, and continues to lengthen until the plant is exhausted. On the other hand we observe, in the Sweet-William, the Elder, and the Hydrangea, the centre flower of a tuft opens first, and the *definite* inflorescence becomes wider and wider, but never grows out in the centre.

Fig. 132.

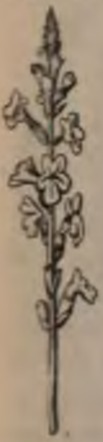


Fig. 133.

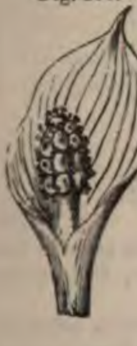


Fig. 134.

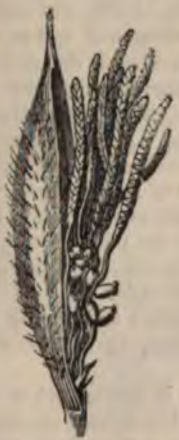


Fig. 135

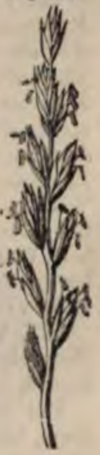


Fig. 132. Spike of *Verbena officinalis*.
Fig. 133. Spadix and spathe of *Calla*.
Fig. 134. Compound spadix and spathe of a Palm.
Fig. 135. Spike, with spikelets, of *Lolium*.

124. The flowers generally open in the order of their development; and thus, when an *indefinite* inflorescence is of a flat-topped or crowded character, the outer flowers open first and the central last, as in the capitula of the Compositæ. Hence the indefinite forms of inflorescence are sometimes called *centripetal*, and the definite *centrifugal*.

There is an exception to the ordinary regularity in the capitula of *Dipsacus* (Teazel), where the florets open first halfway up, and then proceed both centripetally and centrifugally.

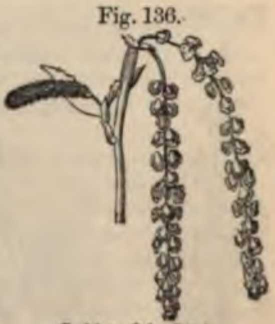
125. Of the Indefinite Inflorescence the following are the most important forms :—the *spike*, the *raceme*, the *corymb*, the *panicle*, the *umbel*, and the *capitulum*.

Of the Definite Inflorescence the chief kinds are, the *cyme* (with its modifications), the *fasciculus*, and the *cœnanthium*.

126. The *spike* is a long simple axis or *rachis* bearing sessile flowers, either standing at intervals, as in the Vervain (fig. 132), or crowded, as in the common Plantain, *Triglochin*, and many Sedges.

Several modifications of the spike have distinct names. When the rachis bears large, persistent, imbricated scales, it forms a *cone* or *strobile*, as in the Firs and Pines. When it is thick and fleshy, with the flowers more or less imbedded in it, the term *spadix* is applied, of which the Araceæ furnish examples (fig. 133); the same term is conveniently retained when this fleshy axis is branched, as in the Palms (fig. 134). The so-called spikes of many Grasses, such as Wheat, Barley, Rye-grass (fig. 135), Cat's-tail-grass, &c., are also compound spikes, since in place of single flowers the rachis bears *spikelets* or short axes with several sessile flowers. The term *catkin* (*amentum*) is applied to the pendent, often caducous, spike-like inflorescence of the Willow, Poplar, Birch (fig. 136), and the male inflorescence of the Oak, Filbert, Chestnut, &c.; in these the bracts have sometimes *one*, sometimes *several* flowers in their axils.

Fig. 136.



Catkins of the Birch.

127. The *raceme* differs only from the spike in having the flowers distinctly stalked, as in the Hyacinth, Mignonette, the Portugal Laurel, &c.

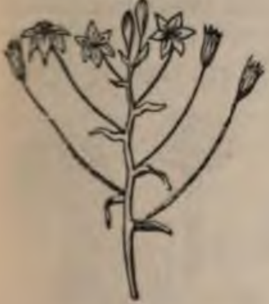
The *corymb* is formed when the flowers originate as in the raceme, but the lower ones are raised on longer stalks than the upper ones, so as to bring them all nearly on a level, as in *Ornithogalum* (fig. 137) &c.

As already noticed, a corymbose inflorescence sometimes grows out into a raceme while the fruits are ripening, as is seen in many Cruciferæ. The relation between the two forms, or, more properly, between the panicled and the corymbose state of the same inflorescence, is well seen in comparing a Cauliflower as fit for the table, with the expanded inflorescence of the same plant when allowed to run to seed.

128. The *panicle* is formed when the lateral buds produce ramified axes instead of single flowers (fig. 138); it is hence merely a compound or branched raceme; when the lower branches extend out

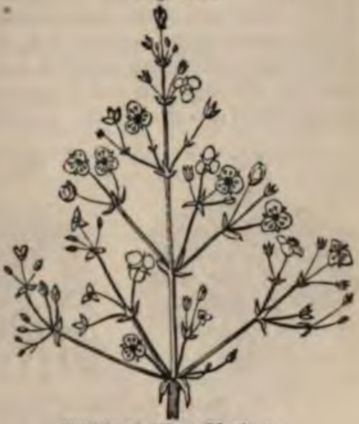
further horizontally, and the entire inflorescence thus becomes pyramidal, the term *thyrse* is occasionally used (Horse-chestnut).

Fig. 137.



Corymb of *Ornithogalum.*

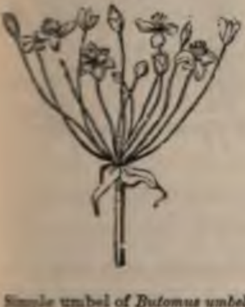
Fig. 138.



Panicle of *Alisma Plantago.*

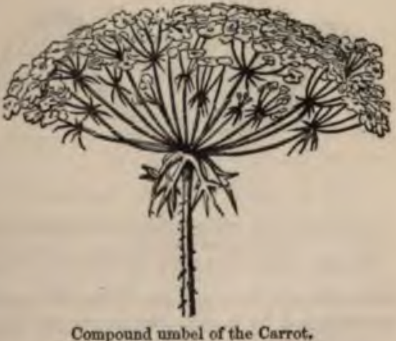
129. The *umbel* is formed by a number of single flowers borne on long stalks of nearly equal length arising from one point, as in the

Fig. 139.



Simple umbel of *Butomus umbellatus.*

Fig. 140.



Compound umbel of the Carrot.

common Cherry, the Onion and its allies, *Butomus umbellatus* (fig. 139), the Cowslip (fig. 130), &c. In the family of Umbelliferæ, so called from the prevalence of this inflorescence, the umbels are mostly *compound* (fig. 140); that is, the first set of radii do not bear flowers, but secondary sets of radiating branches, forming *umbellules*, or secondary umbels.

Umbels usually have an involucre at the base of the radii, as noted above (§ 122). The simple umbels of the Onion group are originally enclosed in a membranous spathe.

130. The *capitulum* is mostly formed by the floral axis expanding into a thickened mass, surrounded by an involucre of overlapping bracts, presenting a convex, flat, or concave surface (*common receptacle*), upon which are crowded a number of sessile flowers, as in the families of Compositæ and Dipsaceæ) (figs. 141–146). In the Compositæ there are often little membranous bracts (*paleæ*) at the outside of each flower (figs. 145, 146); in the Dipsaceæ each flower is surrounded by a cup-like involucre (fig. 142).

Fig. 141.

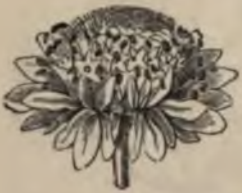


Fig. 142.

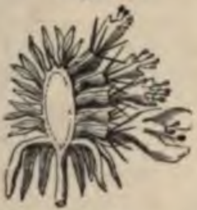


Fig. 143.

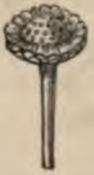


Fig. 144.

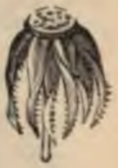


Fig. 141. Capitulum of *Scabiosa*.
Fig. 142. Vertical section of the capitulum of *Scabiosa*.
Fig. 143. Receptacle of Daisy with the florets removed.
Fig. 144. Receptacle of Dandelion with the florets removed.

Fig. 145.

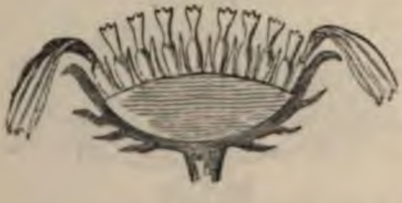


Fig. 146.

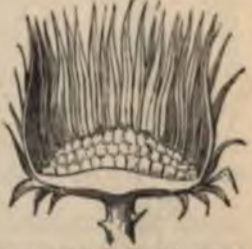


Fig. 145. Section of a capitulum of a Composite plant with paleæ at the base of the tubular and ligulate florets.
Fig. 146. Section of an empty capitulum of a Composite plant with a paleaceous receptacle.

The flowers crowded together in the capitula of Compositæ are small and of various forms, so arranged as to give the whole the outward aspect of a single flower; hence this inflorescence was formerly called a *compound flower*, and its involucre a *common calyx*.

131. The flowers in the capitula of the Compositæ are called *florets*; and different names are applied to this inflorescence, according to the mode of arrangement of the florets. In the Daisy, we observe

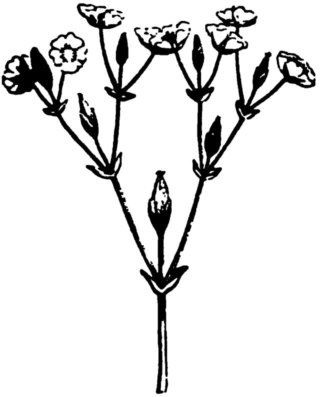
a yellow middle *disk* and a white or pinkish *ray*; the *disk* is composed of florets different in character from the spreading florets of the *ray* (fig. 145). Some capitula are wholly *discoid*, such as those of Groundsel (*Senecio vulgaris*), of Thistles, &c.; others are wholly *radiant*, such as those of the Dandelion, Lettuce, &c.

It should be observed that cultivation tends to convert tubular florets into spreading ones, and so to obliterate the yellow disk or "eye," as we observe in the Dahlia, garden Daisy, &c.

132. Capitula of less marked character are found in other families, where, however, the involucre is wanting; for example, the flowers of Clover (*Trifolium*) have a capitular arrangement, as also those of many Proteaceous plants (*Banksia*).

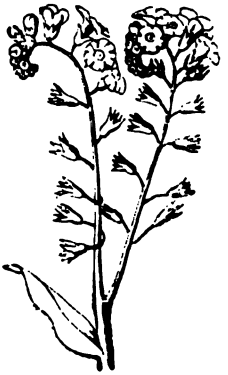
133. The term *cyme* (fig. 147) is very general in its application; for it is used in reference to a number of forms more or less resembling outwardly the raceme, corymb, and others of the indefinite type, but all agreeing in producing a terminal flower on each shoot, and continuing the subsequent evolution by axillary development.

Fig. 147.



Paniculate cyme of *Cerastium*.

Fig. 148.



Scorpioid cyme of *Myosotis palustris*.

The loose cymose inflorescence of many Caryophyllaceæ illustrates the *definite* mode of growth very clearly: the primary axis terminates in a flower, then branches arise in the axils of a pair of bracts lower down; these branches repeat the process, and their branches again, until the flowering shoot is exhausted.

134. When the cyme is loose and irregular, no special term is added to this distinctive name. But if the axillary branching goes on to many degrees, and the peduncles acquire such lengths that the outline of the whole inflorescence becomes rounded, we have a *globose cyme*

(fig. 149), as in the Snowball (*Viburnum Opulus*). If the outer branches spread and grow up so as to produce a flattish or convex collection of flowers, as in the Elder and the garden Hydrangea, it is called a *flat* or *corymbose cyme* (fig. 151).

Fig. 149.

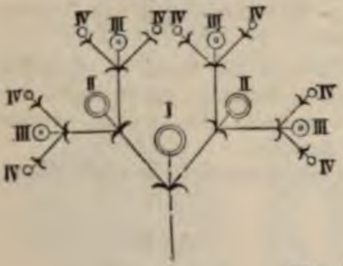


Fig. 150.

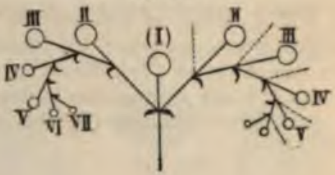
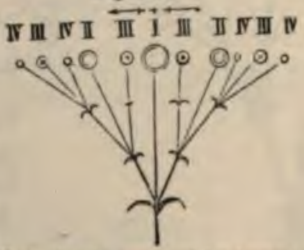


Fig. 151.



Figs. 149-151. Diagrams illustrating the centrifugal development of cymose inflorescences. Fig. 149 a globose, fig. 150 a scorpioid, and fig. 151 a corymbose cyme.

In some cases the axillary buds are only developed on one side of the primary axis, and so on with the secondary axes: in this way an inflorescence resembling a raceme is produced; but the axillary evolution of each new bud gives the structure a circinate or scroll-like form during the development, which at once distinguishes this *scorpioid cyme*. It is very characteristic of the family of the Boraginaceæ (figs. 148 & 150).

135. The *fasciculus* is a cymose collection of nearly sessile flowers, forming a dense flat-topped bunch, such as we see in the Sweet-William and other species of *Dianthus*. Where a cymose tuft of only a few flowers, crowded together in this way, occurs in the axil of an ordinary leaf, the inflorescence is sometimes called a *glomerulus*, as in many of the Labiatæ.

136. In the Fig the peduncle or common receptacle is fleshy and excavated (fig. 152), the flowers being inside and developed centrifugally; in *Dorstenia* (fig. 153) the receptacle is flat or slightly concave on

the top, while in *Artocarpus* and other cases the flowers are on the outside of a convex peduncle. These forms of inflorescence are only slight modifications of the *capitulum*. The term *cœnanthium* has been used to designate them, but is now rarely used.

Fig. 152.

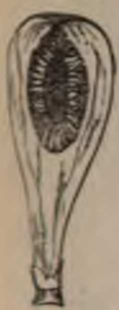


Fig. 153.

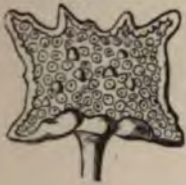


Fig. 154.

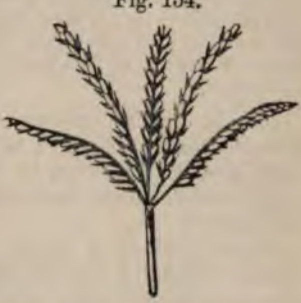


Fig. 152. Cœnanthium of the Fig; the flowers inside the excavated fleshy receptacle.
Fig. 153. Cœnanthium of *Dorstenia*; the flowers imbedded in the fleshy receptacle.
Fig. 154. Compound inflorescence of *Digitaria*.

137. Some plants, especially herbaceous perennials, have what is called a *compound inflorescence*, wherein the flowering region of the stem appears to be composed of a number of distinct inflorescences arranged on a regular plan. The plan of the ramification of the main axis may be the same as that of the individual inflorescences, as in the Umbelliferæ, where both the primary and the secondary umbels unfold centripetally; sometimes the separate inflorescences are arranged in a different form belonging to the same class, as in the case of the umbellate collection of spikes in certain Grasses (*Digitaria*, fig. 154) &c.

In other cases there is a mixed condition, since in many Compositæ the individual capitula are centripetally developed, while they succeed one another on the main stem in a centrifugal or cymose order; in the Labiatæ the cymose axillary glomerules (which, occurring opposite to each other, form *verticillasters* or false whorls) are developed from below upwards, the main stem being indefinite, and they are often crowded together above so as to form a kind of compound spike.

The general facts of the morphology of the different forms of inflorescence of each type are easily seen to be conformable to the laws ruling the development and ramification of the vegetative stem. Buds are either terminal or axillary to bracts: sometimes, indeed, the bracts are suppressed; but even in families where this is almost universally the rule, they make their appearance occasionally in abnormal examples. The occurrence of a number of buds or flowers crowded on one point arises merely from the non-development of the internodes, as in fasciculate leaves, &c.; and the remembrance of this at once explains the close relation of all the indefinite forms of the inflorescence. Thus, suppose we take a *capitulum*, and imagine each of the florets raised on a long peduncle, it would become an *umbel*: if the peduncles branched in like manner to the primary stalk, we should have a *compound umbel*. If, instead of branching, the receptacle of the capitulum grew up into a long straight axis, it would become a *spike* with lateral flowers; if these acquired stalks, a *raceme* would result, from which the *corymb* only differs in the greater development of the stalks of the lower flowers, while a ramification of the peduncles would give rise to a *panicle*.

138. In certain cases we have the normal condition of the inflorescence greatly disguised, as in *foliaceous peduncles*, and in cases of what is called *fasciation*, as also where the flower-stalks are apparently removed from their usual place by adhesion of various kinds and degrees.

In many kinds of *Cactus*, as already noticed (§ 57), the stem assumes more or less the outward aspect of a leaf; and when a flower arises on such a stem, it looks like an abnormal growth; but it is really produced from the terminal or axillary bud of an abortive branch. In the Butcher's-broom (*Ruscus*, fig. 155) the single peduncles are flat leaf-like plates, and bear the flowers in the axils of little scales which arise on the upper surface, seemingly from the midrib of a leaf; but these *foliaceous peduncles* grow from the axils of scale-like leaves. In *Xylophylla* (fig. 156) we find a *compound foliaceous peduncle*, consisting of a large leaf-like branch bearing numerous flowers on its margins, arising there in the axils of bracts.

Fig. 155.

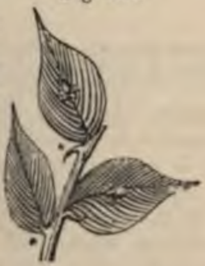


Fig. 156.

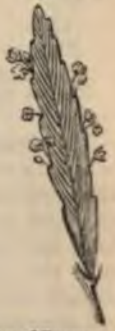


Fig. 155. Foliaceous peduncles of *Ruscus aculeatus*.
Fig. 156. Foliaceous flowering branch of *Xylophylla*.

*Fasciation* is usually an abnormal condition, consisting of the fusion of a number of peduncles into a solid mass, bearing the flowers on the borders. It produces the crest-like condition of the flower-stalk of the garden Cockscomb; and it occurs not unfrequently in the Scrophulariaceæ &c., so as to convert a paniculate inflorescence into a riband-like axis with irregularly scattered, short-stalked solitary flowers.

*Adhesion* of the peduncle to the leaf or bract produces an appearance as if the flower sprang from the latter, as in the case of the Lime-tree. A similar union or, rather, lack of separation between the flower-stalk and the branch produces the *extraaxillary* inflorescence, of some species of *Solanum*. Other cases of extraaxillary inflorescence, wherein the inflorescence is placed opposite to a leaf, as in the case of the Vine, *Solanum Dulcamara*,

&c., are explained by the circumstance that the inflorescence is in reality terminal (as may readily be seen in the young state), but as growth goes on it bends downwards into nearly a horizontal position, while the axillary bud next beneath it developes into a shoot which assumes a vertical direction, thus occupying the position of the inflorescence. Such branches are called by French botanists usurping branches.

139. The inflorescence, like the leaf, varies in its duration. The staminal catkins of the Amentiferæ, such as the Oak, Hazel, Poplar, &c., fall off as soon as the pollen is discharged from the stamens, and they are called *caducous*. In many cases the inflorescence, or the individual peduncles, separate by a disarticulation when the fruit is ripe, as in the Apple, Cherry, &c.; the term *deciduous* is then applied. In the Rose we observe the dried-up fruit long remaining, like the cones of Firs &c., after the seeds have become matured; these are *persistent*. Sometimes the peduncles undergo expansion during the ripening of the seeds, so as to form part of the fruit; such an inflorescence or peduncle is called *excrescent*. The Fig, the Pine-apple, and other fruits are formed of *excrescent inflorescences*; the Cashew-nut (*Anacardium*) has an *excrescent peduncle*.

## Sect. 7. THE FLOWER.

140. The Flower, the characteristic reproductive apparatus of the higher plants, consists of no new elements superadded to the fundamental organs of the vegetative regions, but is merely an assemblage of these organs modified in certain essential particulars so as to fit them for exercising new functions.

A flower is a modified branch, in which the internodes of the stem are seldom developed, while the leaves, arranged according to the general phyllotactic laws, are more or less different in form and texture, have part of their tissues developed into more highly specialized products, and, in part, give origin to buds distinguished both in anatomical and physiological characters from those associated with vegetative leaves.

The study of the modifications or, as they are often called, the metamorphoses of the organs of the flower forms one of the most attractive, and at the same time most important departments of Morphology, and has now advanced far enough to set all general questions at rest; but in an elementary work it is desirable to furnish some of the more striking proofs of the doctrine which is enunciated in the preceding paragraph.

The theory of the construction of the flower rests upon proofs derived from three sources: the most numerous facts are furnished by *teratology*, or the study of abnormal growths; but the strongest confirmation of the views arising out of the observation of such cases is obtained by *comparative anatomy* or analogy, and by the *investigation of progressive development*.

We may, in the first place, remark upon what is taught by the study of development. Flowers are common in which the organs stand in regular circles, and in which the organs of each circle agree in colour, size, and so on; but in many cases we find deviation from this regularity: the arrangement of the organs becomes changed, and the parts of particular circles become more or less different among themselves—as, for example, in the flowers of the Pea-tribe, of Labiatæ, &c. But when we examine the buds of any of these flowers in a very young state, we find the rudimentary organs, with very few exceptions, regularly arranged, and while in the state of cellular papillæ, agreeing exactly in all external characters. The subsequent irregularity is a result of special growth at a later epoch. In didynamous stamens, for example, the longer pair do not exceed the others until a late period of their development.

The original uniformity and homogeneity of the organs of flowers are not always so completely lost in the maturation of the structures, that the different secondary types of organs, sepals, petals, &c. become entirely distinct. The study of comparative anatomy reveals very many cases of transition from one kind of organ to another, illustrating, in a very interesting manner, the doctrines of morphology.

In *Calycanthus floridus* the numerous pieces of the floral envelopes present a spiral arrangement, and it is impossible to find a distinct line of demarcation between the coloured bracts, the calyx, and the corolla. In species of *Cornus* and *Euphorbia*, the coloured bracts of the involucre assume quite the aspect of a coloured calyx or corolla. In the White Water-lily (*Nymphæa*), a transition between sepals and petals is seen in the segments of the calyx, which are green outside and petaloid internally, while we have perfectly petaloid sepals in many flowers, as in Aconites, Larkspurs, &c., and particularly in the showy bulbous Monocotyledons commonly cultivated, *e. g.* the Lily (*Lilium*), Tulip, Crocus, &c.

In the Water-lily, again, we observe a gradual transition between petals and stamens, the latter appearing first as petaloid plates, with anther-structure on the edges. In *Canna* it is the ordinary rule for the stamen to be a kind of petal bearing an anther-lobe on one upper edge. A more or less expanded petaloid state of the filament is not unusual, and in the Mistletoe the stamens are flat, leafy organs, with the pollen developed in the parenchyma of the inner face.

The stamens and pistils being so diametrically opposed in their physiological characters, we naturally do not expect to find any transition between these organs in normal flowers, though in monstrous developments such transitions are frequent. The ovules have been seen bearing pollen, and the anthers ovules.

The study of Teratology, the interpretation of monstrous growths by reference to laws of development more or less interfered with by external agency, is very instructive in regard to Morphology. In the abnormal products of nature or, still more, of art we find illustrations of almost every possible kind of the general proposition above mentioned.

In the first place, cases have been not unfrequently observed where the entire flower has been replaced by a fascicle of green leaves, especially in the Alpine Strawberry. In wet seasons it is not uncommon to find flowers of the White Clover with more or less of the organs modified in this way, the pistil, one or more of the stamens, &c. appearing in the form of green leaves, occasionally compound and ternate, as on the stem below. In the Double Cherry of gardens, the place of the pistil is often occupied by a pair of green leaves; in the Fraxinella a circle of green leaves has been observed in the place of the ovary.

Metamorphoses within the limits of proper floral organs are still more common. Thus, almost all polypetalous flowers, and many monopetalous, are capable of being "doubled" by cultivation, that is to say, the number of petals may be increased at the expense of the stamens, or of these and the pistils. For example, the Wild Rose has but five petals, and many stamens and pistils, but in our garden Roses the numerous stamens and pistils are often altogether replaced by petals. In many cases intermediately formed structures exist in such double flowers: in the double early Tulip, for example, we almost always find monstrous organs, half-petal and half-stamen, and even half-stamen and half-carpel; the same may be observed in double Pinks and Carnations. Illustrations obtained in this way might be multiplied *ad infinitum*. It should be observed, however, that in double flowers we frequently find not only all the essential organs replaced by petals, but an actual multiplication of the natural number of organs, as in Roses, Camellias, double Daffodils, &c.

In the last place, we may advert to the phenomena of the abnormal evolution of buds within the limits of flowers. Cultivated Roses sometimes send out a leafy shoot from the centre (prolification), the terminal bud not becoming arrested as is natural; on Apples and Pears we occasionally see one or two leaves growing out from the summit, from the same cause. In addition to this, the organs of the flower may assert their foliar nature, by producing flower-buds in their *axils*, like stem-leaves. This has been observed in the case of the petals of *Celastrus scandens*, and also of *Clarkia elegans*, and occurs sometimes in garden Roses*.

These general observations will serve to show the essential homology of all the lateral organs of flowering plants with ordinary leaves, and more especially with the vaginal or leaf-scale portion of the leaves. The laws under which the varieties of form &c. are produced within the limits of the flower all cooperate to substantiate the same general principles.

141. The organs of flowers have been enumerated in a former Section (§§ 21–25):— 1, the *sepals*, forming the *calyx*; 2, the *petals*, forming the *corolla*; 3, the *stamens*, forming the *andrœcium*; and, 4, the *carpels*, forming the *pistils* or *gynœcium*. That portion of the peduncle upon which all these organs are attached is called the *receptacle* or *thalamus*; it seldom has the internodes much developed, but is more or less expanded horizontally. When it forms a flattened surface above, its centre corresponds, of

Fig. 157.

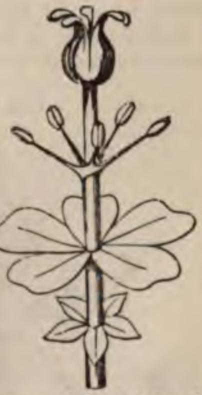


Diagram of the 4 circles of a typical 5-merous flower, separated by internodes.

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* A general review of these abnormal or unusual formations, and of the inferences that may be derived from them, is given in Dr. Masters's 'Vegetable Teratology,' published by the Ray Society.

course, to the apex; and we may thus say that the above-named organs succeed each other from without inwards, or from below upwards.

The accompanying diagram of the floral whorls (fig. 157) illustrates the theoretical construction of a perfect and symmetrical flower. Here the internodes are imagined to be developed between the separate circles of the flower—an arrangement which does occasionally occur in nature.

142. All axillary flowers arise in the angle between a bract or leaf and the stem; from this is taken the rule as to relative position of organs, in describing flowers. The side of the flower next the stem is the upper or posterior part, that next the bract the anterior or lower; and in the ground-plans often used to represent the construction of flowers, it is important to mark the places of the axis and the bract, the former being represented behind, the latter in front.

In the rare cases where flowers are truly *terminal*, there is no proper back and front; but in plans of these, the position of the last leaf or bract should be shown. When bracts are suppressed, as in the Cruciferæ, we of course find the back of the flower by the position of the organs in reference to the parent stem.

143. Since the organs of flowers are modified leaves, we naturally seek for laws of arrangement corresponding to the phyllotaxy of stem-leaves; and we find that the so-called whorls of organs, especially of the calyx and corolla, are often really spiral cycles of organs developed successively on the $\frac{1}{3}$ or $\frac{2}{5}$ plan, but reduced into apparent whorls by the absence of internodes.

This is distinctly the case in such a calyx as that of the Rose, where the sepals are imbricated and stand quite on the $\frac{2}{5}$ plan (figs. 158–160).

Fig. 158.

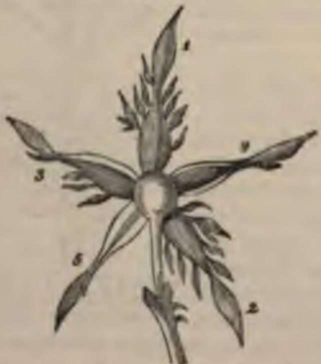


Fig. 159.

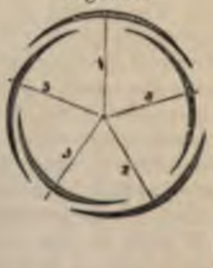


Fig. 158. Calyx of the Rose; the numbers indicate the sequence of the sepals from wi inwards, or from below upwards.

Fig. 159. Section of the æstivation of the calyx of the Rose; the numbers as in the prec figure.

In the ternary floral envelopes of many Monocotyledons we find illustrations of the $\frac{1}{3}$ type. Sometimes the spiral arrangement is still more evident, especially where there exist great numbers of a particular kind of organ, as in the mixed petals and stamens of *Nymphæa*, and the multiple pistils of *Ranunculus*, *Magnolia*, &c. In *Calycanthus* all the organs follow on in a continuous spiral.

In other cases the floral organs are developed simultaneously, when a true whorl is produced.

**144.** According to the number of organs in a cycle or apparent whorl, these are distinguished as *dimerous* or *binary*, *trimerous* or *ternary* (fig. 161), *tetramerous* or *quaternary*, and *pentamerous* or *quinary* (fig. 162). The ternary arrangement is by far the most common in the Monocotyledons, the quinary in the Dicotyledons.

Fig. 160.

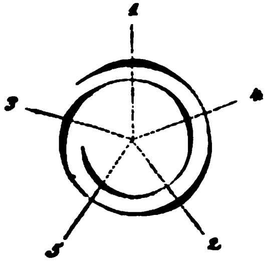


Fig. 161.

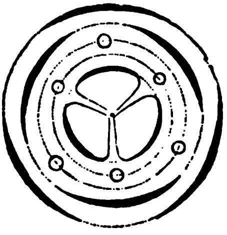


Fig. 160. Diagram of the $\frac{2}{5}$ spiral arrangement of leaves, for comparison with fig. 159.
Fig. 161. Diagram or ground-plan of the 3-merous flower of the Tulip.

Most frequently the calyx and corolla have an equal number of parts; the number of organs is prone to increase in the staminal circles, and still more frequently to diminish in the carpellary whorl.

**145.** In the majority of cases we find the organs of each successive whorl developed alternately with, and not opposite to, those of the preceding circle.

From this the whorls would appear to resemble the decussating whorls (§ 68) of true leaves, rather than regularly succeeding spiral cycles. We have seen that these decussating whorls are closely related to the spiral cycles; but the relations are not clearly made out. Moreover we find in the very numerous cases of flowers with the organs imbricated in the bud, that the spiral arrangement is very evident, and the whorled appearance presents itself only after the expansion of the flower. Now, if the $\frac{1}{3}$ or $\frac{2}{5}$ cycles succeeded regularly, the organs of successive cycles should be opposite and not alternate. A. de Jussieu has supposed that the organs are arranged on the spiral $\frac{5}{13}$ type in all trimerous and pentamerous

Fig. 162.

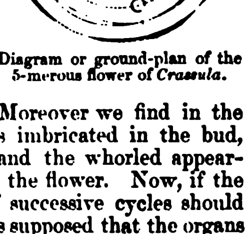


Diagram or ground-plan of the 5-merous flower of *Crassula*.

flowers with imbricated æstivation. Inspection of the diagrams in a former page (43) will show with how little displacement the organs of such flowers may be arranged on this type; and there is much probability that the alternation of spirally arranged cycles results from some such cause, while the alternation of organs in flowers with valvate æstivation is referable to the same laws as the decussation of whorls of leaves. The exceptional cases of opposition of organs will be explained presently.

146. The typical flower in our diagram consists of four circles of organs equal in number of parts, and with the parts regularly alternating. A flower thus presenting all the whorls is called *complete*; the organs in each circle being similar, it is *regular*; and the number of organs in each circle being the same, it is moreover *symmetrical*.

147. Almost every kind of deviation and combination of deviations from this type are met with; but the modifications are referable to distinct causes, which admit of classification under a few general heads. 1. Alteration of the number of circles, or of the number of organs in the circles; this may arise either from *multiplication*, or from *suppression* or *abortion* of parts. 2. Union of the organs together; this may be merely coalescence of the margins of organs of the same whorls (*cohesion*), or confluence of normally distinct whorls (*adhesion*). 3. Unequal development or degree of adhesion in the organs of particular whorls, producing *irregularity*. 4. Irregular development either of the receptacle, or production of out-growths from various organs by *enation*. 5. Substitution of one organ by another (*metamorphosis*).

Dr. A. Gray has furnished an interesting illustration of these laws of modification, from a family (Crassulaceæ) in which different kinds of deviation occur together with examples of very symmetrical flowers. In *Crassula* (fig. 162) is found a simple symmetrical pentamerous flower, with five sepals, five petals, five stamens, and five pistils, all regularly alternating, and only slightly confluent at the base. In *Tillæa* some species have four, some only three organs in each whorl, but the flowers are still regular and symmetrical. In *Sedum* (Stone-crops, &c.) the flowers of some species are pentamerous, those of others tetramerous, but here the number of stamens is doubled by the introduction of an entirely new circle of these organs (*multiplication*). *Rochea* has the margins of its petals slightly *coherent*, while in *Grammanthes* the petals and sepals are respectively *coherent* more than halfway up. *Cotyledon* has *coherent* envelopes, and a double series (*multiplication*) of stamens as in *Sedum*, to which is added an *adherence* of the stamens to the tube of the corolla. In *Penthorum* the five styles are *coherent* firmly together below, while in some cases its petals are *suppressed*. In *Sempervivum* (Houseleek) the number of sepals, petals, and pistils varies in different species from six to twenty, and the stamens from twelve to forty.

148. *Multiplication* of the number of circles is very common, especially as regards the stamens. In the trimerous flowers of Liliaceæ and Amaryllidaceæ there are six stamens standing in two circles of three. In the Poppy family the tetramerous circles are still more multiplied;

and in the Rose, Buttercup, &c. we have further examples. When the number exceeds three or four circles of one kind of organ, the organs are said to be *indefinite* in number, and the verticillate arrangement becomes very indistinct in the opened flower. In the White Water-lily we have multiplication both of petaline and staminal circles; and in *Magnolia*, *Ranunculus*, &c. the pistils are much multiplied, exhibiting in these a distinctly spiral arrangement.

Multiplication of circles occurs abnormally in the *double* flowers of gardens, in which we often find far more organs than exist in the normal state, as in Daffodils and other flowers where the organs are naturally few in number.

149. Multiplication of the organs in particular whorls occurs in a number of flowers, and is explained differently by different authors. Sometimes the multiplication is *collateral*, a pair of stamens, for example, standing in place of one; in other cases the organ is divided transversely into an inner and outer part or into a fasciculus of organs. The real cases of collateral multiplication may probably be explained by the circumstance that the staminal leaf, in these cases, as in an ordinary lobed or compound stem-leaf, becomes subdivided and thus forms a *lobed* or *compound stamen*. The multiplication where organs stand one within the other, or in tufts, may perhaps be referred to developments in the axil of the floral leaves or to [illegible], when they are not better interpreted by supposing suppression of whorls, with collateral *chorisis* of those retained.

The doctrine of *chorisis* or *dédoublement*, in which organs are supposed to split into layers, seems to rest on very insecure foundations. Some regard the pairs of long stamens in the tetramerous flowers of Cruciferæ (often represented by forked filaments with double anthers in some species of *Streptanthus*) as formed of a bilobed leaf; but the symmetry is generally better explained by supposing the glands to represent suppressed stamens of three whorls (fig. 163); for a Crucifer (*Megacarpæa polyandra*, Benth.) has polyandrous stamens. The singular stamens of *Fumaria* and allied species are supposed by some to be examples of *chorisis*; by others, and probably more truly, results of irregular confluence. Perhaps the best evidence is furnished by the numerous dimidiate anthers of the Malvaceæ, the tufts of Hypericaceæ and Myrtaceæ; but these are rather due to a progressive outgrowth or exuberant development, whereby an originally simple organ becomes compound, than to any splitting of a perfect organ. The transverse *chorisis* has been imagined to bear relation to the production of scale-like or petaloid appendages on the face of petals, &c., as in *Silene* &c.; but such structures can hardly have any concern in the

Fig. 163.

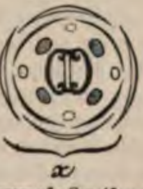


Diagram of a Cruciferous flower: the inner stamens (shaded) form the long pairs; in the outer circle the anterior and posterior stamens (dotted) are replaced by glands.

multiplication of organs, since we find that in double Daffodils, containing fifty or sixty petals, every one of these possesses its process, representing a segment of the nectary found in the throat of this flower. The transformation of such a scale is supposed to give birth to the *opposite* stamens of Rhamnaceæ, the opposite groups of stamens in Tiliaceæ, &c. But opposite solitary stamens, such as those of Rhamnaceæ and Primulaceæ, probably arise from the suppression of an outer staminal circle. Moreover such scales are usually mere outgrowths produced by *enation* from the petals at a comparatively late stage of their development.

150. In describing the phenomena of diminution of the number of circles or organs of flowers, it is convenient to distinguish between *suppression* or total absence, and *abortion* or partial absence, when the organs are represented by imperfect or rudimentary structures.

A *complete* flower possesses a calyx and a corolla; the corolla, and even the calyx also, are wanting in some flowers, which are termed *incomplete*; when the corolla alone is wanting, the flower is *apetalous*; the term *naked* is occasionally applied to flowers without any floral envelopes.

The terms *dichlamydeous*, having calyx and corolla, *monochlamydeous*, having calyx alone, and *achlamydeous*, destitute of floral envelopes, are used by some systematic botanists in place of the above. These conditions are not very secure bases for systematic divisions, since it is not uncommon to find apetalous plants in Orders having ordinarily complete flowers, as in the Caryophyllaceæ (*Sagina* &c.); the apetalous condition, however, is constant in a large number of orders; and familiar examples occur in the Nettle family, the Chenopodiaceæ, the Amaranths, &c. Achlamydeous flowers occur in the Willows, *Callitriche*, &c. as a rule, while they also occur, in exceptional cases, even sometimes on the same plant with complete flowers, as in *Viola* and *Impatiens*.

151. When *essential organs* (stamens and pistils) of both kinds are present, the flower is called hermaphrodite (this condition is indicated by the sign ☿). In many plants one of the circles of essential organs is suppressed, so that a given flower has only stamens or only pistils; such flowers are termed *unisexual* or *diclinous*. The diclinous flowers are called respectively *staminiferous* or *male* (♂), and *pistilliferous* or *female* (♀). When flowers of both kinds occur on the same plant, this is called *monœcious* (Oak, Birch, Vegetable Marrow, &c.); when they are on distinct individuals, the plant is termed *diœcious* (Hop, Willow, Bryony, &c.); when, as in some cases, the imperfection results from a kind of regular abortion rather than total suppression, and the same plant or species exhibits at once staminate, pistillate, and hermaphrodite flowers, it is termed *polygamous* (*Parietaria*, many Palms, and Maples, &c.). Some plants bear *neuter* flowers, destitute of both stamens and pistils: such is the case naturally with the outer florets of many Compositæ, and it is constantly seen in the garden Snowball (*Viburnum Opulus*) and *Hydrangea*.

The *diclinous* condition is often typical in certain families, such as Amentiferæ, &c.; but cases occur not unfrequently in exceptional genera of ordinary hermaphrodite families, as *Ruscus* among the Liliaceæ; or in exceptional species (by abortion), as in *Lychnis dioica*; sometimes it occurs by abortion in species normally possessed of perfect flowers, as in *Asparagus*.

152. The suppression of an entire circle necessarily renders a flower apparently unsymmetrical; for when the corolla is absent, we find the stamens commonly *opposite* the segments of the preceding circle, as in *Chenopodium*; but this is really in accordance with the normal type, as the stamens should be opposite the sepals, the intermediate petals (here suppressed) alternating with both. Not unfrequently we find abortive organs, such as sterile filaments or "glands," of various kinds forming circles which restore the symmetry of apparently unsymmetrical flowers.

The cases of unsymmetrical conditions arising from the opposition of the organs of succeeding whorls are explained by some authors entirely by the doctrine of suppression or abortion; others refer some of these cases to *chorisis* (§ 149). In *Geranium* we find alternating with the petals five little glands which must be regarded as abortive stamens, since in the succeeding whorl the five stamens alternate with these and stand *opposite* the petals; the five innermost and longer stamens, again, are opposite the glands. In *Erodium* the outermost row is represented by glands, the second row by sterile filaments, and only five perfect stamens exist. Much the same conditions occur in the Linaceæ. On the ground of such facts as these, the opposition of the stamens to the petals in Rhamnaceæ, Byttneriaceæ, the Vine, &c. has generally been explained by supposing a circle of stamens to have been suppressed between the petals and the existing stamens. Several recent writers attribute the stamens of Rhamnaceæ to chorisis of the petals with suppression of the true stamens, extending the same explanation to Byttneriaceæ and the Vine, where the true stamens are represented by sterile rudiments or glands *within* the existing stamens. In Primulaceæ, the opposition of the stamens to the petals is obviously a result of suppression; for in *Samolus* we find five lobes on the throat of the corolla alternating with the petals, while *Lysimachia ciliata* has five sterile filaments in addition to five perfect stamens. Some of these cases of altered symmetry are due to enation.

153. *Suppression* or *abortion* of part of the organs of one or more circles is a very common cause of want of symmetry. This occurs by far most frequently in the carpellary circles, as might be expected from the organs being crowded on the point of the receptacle (multiplication of carpels occurring, on the other hand, where the receptacle is unusually developed); the stamens exhibit it not unfrequently; and it is observed also in the petaline whorl, and even in the calyx.

Symmetrical flowers may be either dimerous, trimerous, tetramerous, or pentamerous throughout; and when the organs are equal in all the circles, the flowers are *isomerous*: we have isomerous dimerous flowers in *Circæa* (fig. 164) and *Syringa* (fig. 165), isomerous pentamerous flowers in *Crassula* (fig. 162), before referred to; but, generally speaking, one or other of the whorls exhibits partial suppression.

It is rare to find the sepals *partially* suppressed: perhaps we may consider this to be the case as regards the limb of the sepals in such instances as the pappus of *Bidens*. The corolla exhibits partial suppression in some Leguminosæ, where, although the plan of the flowers of the order is pentamerous, in *Amorpha* only one petal exists; a transition towards this occurs in other genera of the order, where, indeed, the four petals here suppressed are generally considerably smaller. In the Larkspurs one petal is constantly suppressed, while the others are of irregular form; and in Aconite three out of the five petals are inconstant in their occurrence, being, even when present, mere petaloid scales.

Fig. 164.

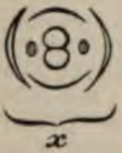


Fig. 165.

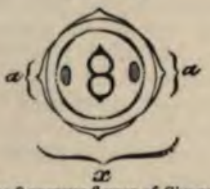


Fig. 166.

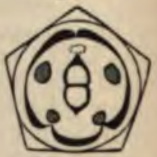


Fig. 164. Ground-plan of the 2-merous flower of *Circæa*: *x* represents the bract.
Fig. 165. Ground-plan of the Lilac, with 2-merous circles: *x*, the bract; *a*, *a*, bracteoles.
Fig. 166. Ground-plan of a labiate flower, with didynamous stamens; the posterior one (dotted) suppressed.

The stamens are mostly *isomerous*, with either one, two, or more whorls, when the floral envelopes are regular, although there are well-known exceptions to this. The supression or partial abortion of some of the stamens is most common where the flowers are irregular. This suppression is well seen in the irregular monopetalous Orders, where we find curiously graduated illustrations of the phenomenon. Thus, in the Scrophulariaceæ, belonging to the pentamerous type, there are usually but four stamens, but *Verbascum* has the fifth (not always fertile); *Pentstemon* has four perfect stamens and a sterile filament; and in *Scrophularia* the fifth is represented by a scale in the upperside of the corolla. In *Veronica* three are suppressed, and only two remain. In the Labiatæ (fig. 166), again, one stamen is ordinarily suppressed; not unfrequently two of these appear as sterile filaments; and in *Salvia*, *Monarda*, and other genera only two stamens exist.

Either *multiplication* or *suppression* is almost the rule in the carpellary circle, the isomerous condition being rather the exception. Six carpels, or a double circle, occur in the 3-merous flowers of *Triglochin* (fig. 167); and we have mentioned the occurrence of five carpels in the pentamerous flowers of *Crassula* and *Sedum* (§ 147); in the nearly allied Saxifragaceæ the carpels are usually reduced to two. In Araliaceæ, *Aralia* has five carpels, different species of *Panax* three and two, while in the allied order Umbelliferæ the number 2 is universal in the carpellary circle, although all the other circles remain pentamerous. In Rosaceæ we have almost every conceivable condition; for while multiplication takes place to a great extent in *Rosa*, *Fragaria*, and allied genera, the normal five carpels occur in *Spiræa* and the Pomaceous suborder; in *Agrimonia* the number is reduced to two; *Sanguisorba* has two or one; while in the Drupaceous suborder, in *Prunus* &c., only one carpel regularly exists, a condition which is the rule throughout the related extensive pentamerous order Leguminosæ. In Ranunculaceæ the number of carpels varies much. In Berberideæ the outer circles are 2-merous and the carpel is solitary (fig. 168). Suppression of a portion of the carpels is almost constantly found in the monopetalous Orders, where we seldom have more than two.

Fig. 167.

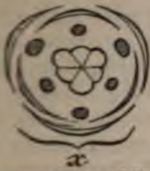


Fig. 168.

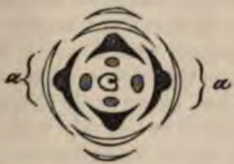


Fig. 167. 3-merous flower of *Triglochin maritimum*, with six carpels; *x* represents the bract.
Fig. 168. Ground-plan of *Epimedium*, with 2-merous circles and a solitary carpel; *a*, *a* are the bracteoles of the pedicel.

Suppression of organs becomes exceedingly striking when associated with suppression of entire whorls. Thus, in *Callitriche* the floral envelopes are wanting, and while the pistil indicates the tetramerous type, three stamens are suppressed, so that the perfect flowers consist of one stamen and one pistil, and the imperfect flowers often met with are composed respectively of a stamen and a pistil. The latter condition occurs also in the greatly reduced flowers of our native species of *Euphorbia*, in which the involucre encloses one naked female flower, consisting simply of a pistil, and a number of naked male flowers reduced to the condition of a single stamen.

A curious kind of regular suppression, not interfering with symmetry, is sometimes met with, where the typical pentamerous condition is replaced by the tetramerous, either in flowers of the same plant or on different individuals of the same species. Thus, in *Ruta*, in some species of *Sedum*, and some *Alsineæ* the flowers have the organs sometimes in circles of fives and sometimes in circles of fours, without any other accompanying deviations from the character of the species.

154. Union of the organs of the flower consists either in *cohesion* of the parts of a whorl with their fellows, or in *adhesion* of organs of one whorl to those of another. Both occur in almost every possible degree. It must be borne in mind that these terms are often applied to cases wherein there has really been no union of previously disunited organs, but a want of separation between parts which in other cases are disjoined.

155. *Cohesion* occurs in the calyx, producing what is called a *monosepalous* (or gamosepalous) calyx; also in the corolla rather less frequently, forming a *monopetalous* (or gamopetalous) corolla. With these terms are contrasted *polysepalous* and *polypetalous* (or dialysep-petalous), used to indicate that the sepals and petals are *distinct*, i. e. not coherent.

In the Vine the petals cohere above, while they are distinct below, and the flower opens by the separation of the corolla from the receptacle; the sepals of *Eschscholtzia* are entirely coherent, and fall off like a cap.

Union is less common among the stamens; but in some Orders they are coherent by their filaments into one piece (*monadelphous*), in others into two or more parcels. Other plants have the anthers coherent (*syngenesious*), while the filaments are free; and in some diclinous flowers the stamens are united into a kind of column.

The carpels exhibit every degree of confluence, from a slight coherence at the base to a firm union by their sides, complete confluence of the ovary with the styles free, confluence of ovaries and styles in part or entirely with free stigmas, and complete confluence of ovary, styles, and stigmas. In Asclepiadaceæ we have confluence of the styles, while the ovarian portions of the carpels are only slightly coherent.

The details regarding coherence will be treated of more conveniently in the chapters on the separate organs.

156. *Adhesion* may exist between the inner and outer circles of the floral envelopes, between petals and stamens, and between stamens and pistils, also between calyx, corolla, and stamens with pistil free; or the calyx, corolla, and stamens may all adhere to the pistil. No case is known of adhesion of the three inner circles with a free calyx.

What is commonly termed *adhesion* is more strictly want of separation between parts which ordinarily become detached one from the other during growth.

157. The point of emergence of an organ is inappropriately called its *insertion*; and when an organ is not adherent to any other circle, but emerges directly from the receptacle, it is said to be *free*. When the outer organs are thus inserted on the receptacle, they are called *hypogynous* (fig. 169), signifying below the pistil; if the stamens appear to adhere to the free tube of the calyx or corolla, they are said to be *perigynous* (fig. 170); while if the tube of the calyx or receptacle is

Fig. 169.

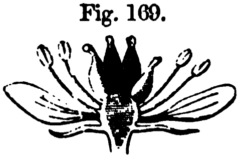


Fig. 170.

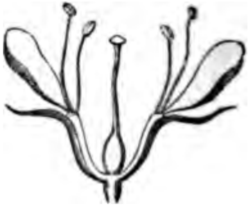


Fig. 169. Hypogynous flower of *Ranunculus*, in section.
Fig. 170. Perigynous flower of *Prunus*, in section.

carried up and adherent to the sides of the pistil, the stamens become apparently *inserted* on the top of the ovary, and are then called epigynous (fig. 171).

Some other terms are used in reference to the insertion of the petals and stamens: thus, *thalamifloral*, or inserted on the receptacle, is synonymous with hypogynous (fig. 169); *calycifloral*, indicating insertion into the throat of the calyx, may agree with either the perigynous (fig. 170) or epigynous (fig. 171) conditions; while *corollifloral*, inserted on the tube of the corolla, is a form of the perigynous insertion.

158. The terms *inferior* and *superior* are occasionally applied to the calyx, according as it is *free* (fig. 169) or *adherent* (fig. 171) to the ovary all the way up; occasionally it is half-superior (*Saxifraga*, fig. 172). The same terms are also applied to the ovary in the reversed sense to indicate the same conditions: *i. e.* when the calyx is inferior, the free ovary is superior, and *vice versâ*.

The terms *perigynous*, &c., and *calycifloral*, &c. are in constant use and very convenient, but they may convey false notions as to actual structure. In the perigynous flowers of Rosaceæ, for example, such as those of *Fragaria*, *Geum*, &c., the stamens appear really to rise from a discoid expansion of the receptacle, forming the supposed throat of the calyx, and in *Rosa*, *Pyrus* (fig. 173), and other similar forms the carpels are really enclosed in an excavated receptacle or *receptacular tube*, from the upper edge of which sepals, petals, and stamens arise.

Fig. 172.

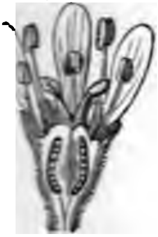


Fig. 171.

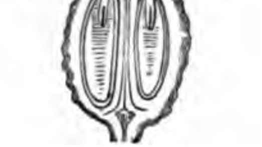


Fig. 173.

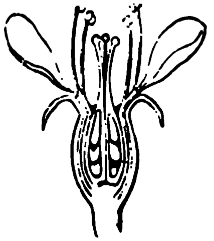


Fig. 171. Epigynous flower of an Umbellifer, in section.
Fig. 172. Flower of Saxifrage in section, with a partially adherent calyx and half-superior ovary.
Fig. 173. Flower of *Pyrus*, in section.

The adherence of stamens to pistils produces what is called the *gynandrous* condition, so remarkable a character of the Orchidaceæ and Asclepiadaceæ.

159. Irregularity of flowers arising from unequal *size*, different

*form*, or unequal *union* of the organs of whorls is extremely common. Different form and size produce irregularity in the floral envelopes and stamens of many plants where these are free; and this is often associated with irregularity arising from suppression. The irregular union occurs alone, or is superadded to all the rest when the organs are coherent; this condition is oftenest found in the floral envelopes, in the stamens less frequently, and in the pistils perhaps not at all.

Irregular polypetalous flowers illustrating this point present themselves in Papilionaceous plants, in Fumariaceæ, Violaceæ, &c.; irregular polysepalous calyces occur in *Aconitum*, *Delphinium*, &c. Stamens are generally alike in the same circle; but in *didynamous* stamens (two long and two short) there is an exception to this. Irregular monosepalous calyces and irregular monopetalous corollas are met with in endless variety of forms, in the majority of which there is a tendency of the component organs of a whorl to associate together in two groups, front and back, so as to produce a bilabiate condition, as in the corollas of most Labiatæ and Scrophulariaceæ. Unequal degree of union of stamens produces the *diadelphous* condition of many Leguminosæ, and the still more irregular polyadelphous condition in the Orange. These points will be further explained in the next Sections.

It may be repeated here, that the deviations from irregularity falling under this head almost universally arise during the development of the bud from its originally regular rudiments.

160. Most flowers have only very short or contracted internodes developed between the whorls; that is to say, the receptacle (§ 141) is usually not lengthened. Exceptions occur to this, however; for in the Caper tribe we have long internodes between calyx, corolla, stamens, and pistil, producing a very curious appearance. In

Fig. 174.

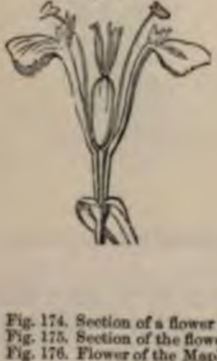


Fig. 175.

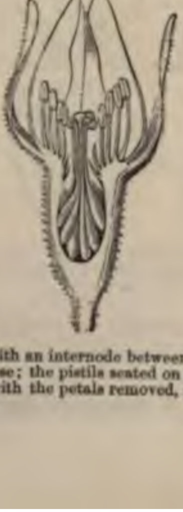


Fig. 176.

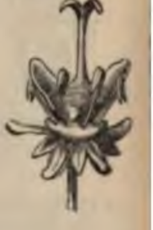


Fig. 174. Section of a flower of *Silene*, with an internode between the calyx and corolla.
Fig. 175. Section of the flower of the Rose; the pistils seated on an excavated receptacle.
Fig. 176. Flower of the Maple (*Acer*), with the petals removed, showing the stamens arising from an hypogynous "disk."

*Dianthus* and *Silene* (fig. 174) there is a short internode between the calyx and corolla, in *Gentiana* between the stamens and the pistil. In the Rose (fig. 175) the receptacle is expanded into a cup, from the inner walls of which the carpels arise; and in *Nelumbium* the carpels are immersed in a large fleshy receptacle. In many cases what is termed *calyx-tube* is in reality a tubular prolongation of the receptacle, from the edge of which the calyx, petals, and stamens arise. In the Pæony the receptacle is raised up into a kind of cup or "*disk*" round the carpels, in *P. Moutan* enclosing them all but the stigmas: the apparently inferior position of the ovary of *Victoria* depends on the discoid development of the receptacle where the outer floral circles are inserted. A ring of similar nature, free from the ovary, occurs in *Alchemilla*. Another condition exists in the Mignonette (*Reseda*), where the cup-like or annular development of the receptacle is inside the floral envelopes, and forms a support to the stamens surrounding the ovary. This form of the "disk," which occurs also in *Acer* (fig. 176), must not be confounded with those depending on the presence of perfect or imperfect whorls of abortive floral organs (§ 195). The epigynous disk of Umbelliferæ (fig. 171) and allied orders is probably a development of the receptacle, since the so-called adherent tube of the calyx is perhaps an excavated receptacle (§ 171). In *Circæa*, and to a greater or less extent in other Onagraceæ, the epigynous process supporting the floral envelopes and stamens is prolonged into a tube above the inferior ovary, surrounding the long free style. Where organs are multiplied, we often find the receptacle lengthened into a conical or clavate body, to give room for the insertion, as with the pistils of *Ranunculus* (fig. 169), *Magnolia*, *Fragaria*, &c.; and this expansion extends down to the region of attachment of the stamens in *Ranunculus*, *Magnolia*, and *Nymphæa*, where it is sometimes thickened, and is called a *torus* or *thalamus*. In Geraniaceæ the receptacle is prolonged into a column in the centre of the confluent styles; and the same occurs to less extent in *Euphorbia*.

161. When a circle of organs is removed from its predecessor by a stalk-like internode, it is called *stipitate*. The column supporting the carpels of *Geranium*, or those of Umbelliferæ, is termed a *carpophore*; the stalk of the ovary of *Gentiana* is a *gynophore*; a stalk above the corolla, supporting both stamens and pistils, is a *gynandrophore*. Considerable influence is exerted in many cases by the *obliquity* of the receptacle, as in Leguminosæ, *Aconitum*, *Delphinium*, and many other irregular flowers.

162. The modifications arising from *enation* have been already alluded to (§ 149), while those dependent on the *substitution* of one organ for another, as in many double flowers where the stamens are replaced by petals, demand only passing notice.

## Sect. 8. The Floral Envelopes.

163. The floral envelopes of a typical flower (§ 21) consist of two circles of organs, forming the calyx and corolla. There is no fundamental difference between sepals and petals (the organs which compose these circles); and the only general definition that can be given is, that the outer circle (or, if only one circle exists, that circle) is the calyx; the corolla consists of the second circle (or sometimes of additional circles) of foliar organs intervening between the calyx and the stamens.

164. The above definition of the calyx is liable to exception in rare cases; for in the Malvaceæ, the Dipsaceæ, and some Rosaceæ the true calyx is double, that is, a circle of smaller organs, resembling sepals, or a tubular cup, stands outside the proper calyx, forming what is called an *epicalyx* (fig. 177). The ambiguity in these cases is removed by the existence of a well-developed coloured corolla inside the calyx.

Fig. 177.

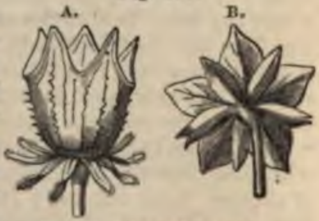


Fig. 177. Calyx with epicalyx.
A. *Hibiscus* (Malvaceæ).
B. *Potentilla* (Rosaceæ).

The epicalyx of Malvaceæ, like that of Dipsaceæ, is perhaps to be regarded as an involucre of bracts. That of *Potentilla* (fig. 177, B) and allied genera is sometimes supposed to represent confluent lateral lobes or stipular appendages of the sepals.

165. A difficulty arises in the exact description of the floral envelopes, from the use of the terms *perianth* and *perigone*, which are applied in a manner that involves confusion, since:—1, these words signify the calyx and corolla taken together when the sepals and petals are all petaloid, as in the Lily, Tulip, &c., and when they are all green and sepaloid, as in the Dock &c.; and, 2, the words are commonly applied to the calyx in the Orders where it regularly exists alone, either in a sepaloid or petaloid condition, as in *Daphne* and the Monochlamydeous orders generally.

The terms *perianth* and *perigone*, which we take as synonymous, are convenient as applying to instances where the distinctions ordinarily traceable between calyx and corolla are not apparent.

166. The arrangement of the floral envelopes in the bud, the *æstivation* or *præfloration*, is a subject of great importance in systematic botany, as affording very regular characters in the majority of the natural orders.

The plans of æstivation given in illustrative works are taken from horizontal sections of the bud just before it opens; and in cases where the sepals or petals are coherent below, the section is supposed to pass through the free lobes of the limb.

167. The æstivation of flower-buds agrees essentially with the vernation of leaf-buds (§§ 112, 113), especially as regards the folding of the individual organs; the sepals and petals may be *reclinate, conduplicate, plicate, convolute, involute* (a still further rolling-in rendering this *induplicate*), *revolute* (in excess becoming *reduplicate*); and an additional case is found in Poppies and some other flowers, where the petals are irregularly crumpled-up, or *corrugate*.

168. Collectively, the arrangement of the organs is either *imbricate, contorted*, or *valvate*, each of which forms, however, has its modifications. The *imbricate* is a natural result of the spiral succession of organs, and with the $\frac{2}{5}$ plan we commonly find what is called the *quincuncial* æstivation (fig. 159). A deviation from the regular spiral order is found in the imbricated buds of Papilionaceous and some other flowers, where the second petal has its margin inside instead of outside the fourth (fig. 178, A); this is called the *vexillary* æstivation, since it occurs especially in Papilionaceous corollas, where the large outer petal is called the *vexillum*.

Fig. 178.

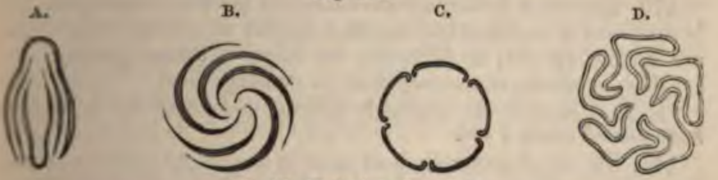


Fig. 178. Æstivation of corollas.

A. Vexillary æstivation of the corolla of a Papilionaceous flower. B. Contorted æstivation of the corolla of *Malva*. C. Valvate æstivation of the corolla of *Vitis*. D. Plicate æstivation of the corolla of *Convolvulus*.

The *contorted* or *convolute* æstivation is produced by the organs standing very obliquely on the receptacle, as it were with one edge turned to the centre of the flower and the other rolled round the next succeeding organ (fig. 178, B).

The *valvate* æstivation presents still more modifications. The margins of the organs may be directly in contact (fig. 178, C), or they may be *involute* (fig. 125), or *induplicate*, or, *vice versâ*, *reduplicate* (fig. 129), or *conduplicate*, in all of which cases the rolled borders only are in contact, and not the absolute margins. When the organs are coherent at their margins, they sometimes become *plaited* or *plicate*, and a kind of combination of this and the contorted form occurs where the projecting plaits are all rolled round in one direction (fig. 178, D).

The calyx and corolla may both have the same æstivation, or they may be different; and these characters generally hold good throughout Natural orders.

In the Malvaceæ the æstivation of the calyx is valvate, and that of the corolla contorted; in *Hypericum, Dianthus*, &c. the calyx is imbricate and the corolla contorted.

Some additional terms are used by recent authors to express minute differences in the æstivation, furnishing valuable characters in some of the large and multiform orders of Monopetalous plants; but it is unnecessary to enter into these minute particulars here.

169. The direction of the spiral in imbricated and contorted æstivation is variable, sometimes even in the same plant: occasionally the direction changes in passing from the calyx to the corolla; at other times it remains the same; and this character is sometimes constant, in other cases very inconstant. In determining the direction of spirals, right-hand or left-hand, it is usual to suppose one's self standing in the axis of the organ; but many authors suppose themselves standing in front of it; for instance, in the place of the bract of a flower, which gives the exact opposite of the former; hence great confusion in the application of the terms *dextrorse* and *sinistrorse*.

### *The Calyx.*

170. The calyx is the outermost circle of the floral envelopes. It is composed of modified leaves, called *sepals*; according as the sepals are distinct (§ 155) or coherent, the calyx is termed *polysepalous* (or *dialysepalous*), or *monosepalous* (or *gamosepalous*).

The exceptions to the absolutely external position of the calyx have been pointed out in § 164.

171. The *sepals* generally bear more or less resemblance to bracts, being attached by a broad base, seldom articulated, without any stalk, and of a green foliaceous texture; not unfrequently, however, their texture is of the coloured and delicate nature described as petaloid. They are usually *entire*; but the margins are sometimes cut, as in the Rose (fig. 158), and they are occasionally reduced to scale-like, or even feathery or hair-like processes. They are likewise subject to the production of pouches, spurs, &c., especially at the lower part, both when distinct and when coherent; and the apex is often more or less prolonged into a point or spine. Their mode of venation is usually like that of the sheath of the leaf.

Some confusion is liable to arise in the condition called a *superior* calyx (§ 158), where the segments are totally free: if we suppose an adherent tube to exist below, such a calyx would be monosepalous; but the so-called calyx-tube is usually a cup-like receptacle, and the sepals arise where they appear to be inserted—for example, in Rosaceæ, Umbelliferæ, Cucurbitaceæ, Compositæ, &c.

172. In the *polysepalous* calyx, if the sepals are alike and symmetrically arranged, the calyx is regular; if some of the sepals are larger than others (*Helianthemum, Cheiranthus* (fig. 179)), it becomes *irregular*; and this is still more the case when the sepals differ in

form as well as size. Some of the most remarkable irregular forms of polysepalous calyx occur accompanied by a petaloid condition, as in *Aconitum* (fig. 180) and *Delphinium*.

The coloured calyces, both regular (*Fuchsia*) and irregular, may be easily mistaken for corollas; but they are known by their exterior position, and in some cases by the existence of a more or less perfect corolline circle within.

173. The direction of sepals (whether distinct or coherent) is indicated by technical terms; thus they may be *erect*, *connivent* (the points turning in), *divergent*, or even *reflexed*.

174. When the sepals are confluent or not separated, the *monosepalous* calyx (fig. 181) is usually described as a whole. The part where the sepals are coherent is the *tube*; the upper boundary of this is the *throat* (*faux*); and the free or spreading portion constitutes the *limb*—composed of *lobes* or *teeth* with intervening *sinuses* when the upper part of the sepals is more or less distinct, *entire* when the sepals are so completely confluent that the compound nature is not indicated by any teeth or fissures at the free edge.

It is necessary not to confound the *receptacular tube* with the *calyx-tube* proper. An investigation of the course of development will show the difference between the two, and generally speaking the position of the petals and stamens; if the latter are *perigynous*, it is probable that the tube below is receptacular. The venation and internal structure will also serve as guides in this matter.

175. The monosepalous calyx is subject to the same kinds of modification as that in which the sepals are distinct. It is either *regular* or *irregular*.

Of the regular kinds we find a large number which present forms admitting of general technical names, such as *tubular* or *cylindrical*, *cup-shaped*, *infundibuliform* or funnel-shaped, *campanulate* or bell-shaped, *urceolate* when the tubular form is expanded below, *turbi-*

Fig. 179.

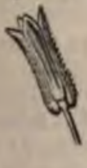


Fig. 180.

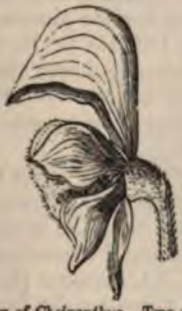


Fig. 181.

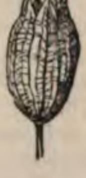


Fig. 179. Irregular polysepalous calyx of *Cheiranthus*. Two of the four sepals are dilated or "gibbous" at the base.
Fig. 180. Irregular polysepalous coloured calyx of *Aconitum Napellus*
Fig. 181. Regular monosepalous calyx of *Silene inflata*.

*nate* or *top-shaped* when expanded above, *inflated* when the lateral view is oval or roundish with a narrow mouth (fig. 181), &c. (See § 182.) In some species of *Campanula* there are regular appendages at the bottom of the sinuses between the teeth. In *Primula* and some other genera the tubular calyx is angular or plaited.

Calyces nearly resembling the above are rendered irregular either by a greater extent of disunion taking place between some of the sepals, the intervening fissures being so much deeper than the others that the teeth become associated in two sets, giving a *bilabiate* condition (fig. 182)—or by irregularities at the base, where a shallow pouch renders the calyx *gibbous*, a deeper one *saccate*, and a long narrow pouch forms what is called a *spur*. In *Pelargonium* this spur adheres to the peduncle.

In some instances a tubular development of the receptacle or flower-stalk simulates the spur of the calyx.

Fig. 183.

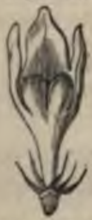


Fig. 182.

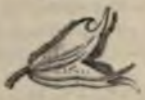


Fig. 184.

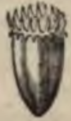


Fig. 185.

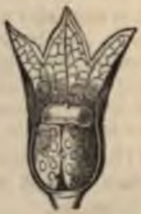


Fig. 182. Bilabiate calyx of *Salvia*.
Fig. 183. Floret of *Scabiosa*, the limb of the calyx in the form of bristles (*pappus*).
Fig. 184. Fruit of *Cichorium*, crowned by the persistent calyx represented by a circle of spines (*pappus*).
Fig. 185. Section of the persistent calyx, enclosing the ripe capsule, of *Hyoscyamus*.

The free portion of the calyx of Compositæ, Dipsaceæ, and Valerianaceæ exhibits a very aberrant condition by appearing in the form of scales, bristles, or feathery or simple hairs, constituting what is called the *pappus* (figs. 183, 184). In *Centranthus* the limb of the calyx is undeveloped when the flower opens, but expands during the ripening of the fruit into a crown of feathered processes.

Further details respecting the characters of the calyx are given under the head of the *Perianth*.

176. The *duration* of the calyx varies much. In the Papaveraceæ it is *caducous*, falling off when the flower opens; if it falls with the corolla soon after fertilization of the ovules, it is *deciduous*; very frequently it is *persistent* during the ripening of the seeds, as in Labiatæ, some Solanaceæ (fig. 185), Compositæ (fig. 184), &c.; the upper part sometimes separates by a circular slit, leaving the base, as in *Datura Stramonium*; occasionally it grows during the maturation of the fruit, and is then *accrescent*, forming in *Physalis* and *Trifolium*

*fragiferum*, for example, a vesicular envelope to the fruit. In the Marvel of Peru and other plants it is *marcescent*, remaining and growing into a firm envelope of the fruit.

### *The Corolla.*

177. The corolla is composed of all the leaf-like organs or floral envelopes situated between the calyx and the stamens; these are called *petals*, and may exist in one or more circles. Where many circles exist, the inner organs often become stunted or deformed, and more or less resemble barren filaments or abortive stamens (*Nymphæa*). Each petal, under ordinary circumstances, intervenes between two sepals.

The petals are either distinct, and then the corolla is called *polypetalous*, or they are more or less coherent (see § 155), and the corolla is *monopetalous*.

When more than one circle of petals exists, the corolla is multiple or double; this is normal in certain plants, but is very liable to occur from transformation of stamens &c., or actual multiplication of whorls, as in cultivated flowers of the Rose, *Camellia*, *Ranunculus*, *Anemone*, &c.

178. Although petals depart more than ordinary sepals from the character of true leaves in colour and texture, they present greater resemblance in some respects, since they usually have a more or less developed petiolar region, which is sometimes of considerable length, at other times a mere thickened point; and they are commonly articulated to the receptacle. The petiolar portion of the petal is called the *claw* (*unguis*), the expanded portion the *limb* (*lamina*) (fig. 186). Petals are likewise more frequently cut at the margins, as in the fringed petals of Pinks and the laciniated petals of *Lychnis Flos-Cuculi*, or they are deeply divided into lobes, as in many Caryophyllaceæ (fig. 187), and the pinnatifid petals of *Schizopetalum* &c. In some cases they exhibit processes on the inner face, which have been supposed to be related to the stipules of true leaves, as in *Lychnis* (fig. 188) &c.

Fig. 186.

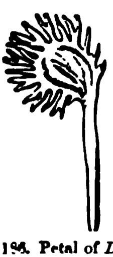


Fig. 187.

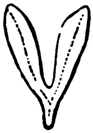


Fig. 188.

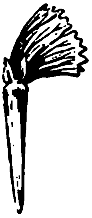


Fig. 189.

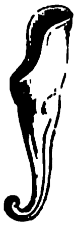


Fig. 186. Petal of *Dianthus*.
Fig. 187. Bilobed petal of *Alsine media*.
Fig. 188. Petal of *Lychnis*, with scales.
Fig. 189. Spurred petal of *Aquilegia*.

The relation of these internal scales or processes to the stipules is inferred from their resemblance to the *ligule* of Grasses. They are, however, generally speaking, merely instances of *enation* or excrescences from the petal, found in a comparatively late stage of the development of the latter.

179. The forms of petals resemble many of those indicated for simple true leaves; in addition to which others occur presenting curved surfaces: these are called simply *concave*, *navicular* or boat-shaped, *cochleariform* or shaped like the bowl of a spoon, &c.; or they may have basal pouches, and be *gibbous*, *saccate*, or *spurred* (fig. 189). Others have peculiar appendages above, such as the *crests* in *Polygala* and the *strap-like* inflexed points in the petals of the Umbelliferæ.

The term *nectary* is vaguely employed to indicate certain structures of varying character intermediate in position between the petals and the stamens, and different in aspect from both.

180. Petals are ordinarily of delicate structure and coloured, whence we derive the term *petaloid*; but they vary in texture from a membranaceous to a thick and fleshy condition, such as we see in *Magnolia*, *Nymphæa*, &c.

181. *Polypetalous* corollas are *regular* when the petals are equal and symmetrically arranged; the individual petals may be themselves either symmetrical or oblique, provided they are all alike. Some of them have received special names, such as:—the *rosaceous*, where there are five spreading petals; the *liliaceous*, where six petals spread gradually from a funnel-shaped origin; *caryophyllaceous*, where five petals have long erect claws from which the limbs turn off at a sharp angle; *cruciform*, where four such long-clawed petals with horizontal limbs stand in the form of a cross, as in the Wallflower, &c. Slight degrees of *irregularity* arise from some petals growing larger than others, as in the case of the outer petals of the outer flowers of the corymbs of *Iberis*, of the umbels of *Umbelliferæ*, &c.; but more stri-

Fig. 190.

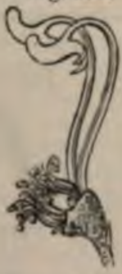


Fig. 191.

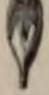


Fig. 192.

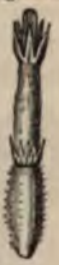


Fig. 190. Flower of *Aconitum* with the sepals removed, showing the two hammer-headed posterior petals (or nectaries) with lateral and anterior scale-like petals, outside the numerous stamens.
Fig. 191. Bilabiate scroll-like petal (or nectary) of *Helleborus*
Fig. 192. Tubular floret of Compositæ.

king irregularity results from unlikeness of the petals and disturbance of symmetry in their insertion or point of emergence. The imperfect corollas of Aconite (fig. 190), Larkspur, &c. are examples of this; and a still more important case occurs in the *papilionaceous* corolla of *Leguminosæ* (figs. 193–195), which is composed of five petals, of which the posterior, the *vexillum* (fig. 194 *a*) or standard, the largest, usually symmetrical in form, is placed transversely; the two lateral (fig. 194, *b*, *b*), mostly oblique in form and small, forming the *alæ* or wings, stand right and left with the edges fore and aft; and the two anterior (fig. 194, *c*, *c*), also small and oblique, often coherent in front, and forming the *carina* or *keel*, also stand with their edges forward.

Examples occur in the large order Leguminosæ of almost every modification of the papilionaceous corolla, approaching to regularity in *Baptisia* for instance, and still more in *Cassia*. Irregular corollas exist also in the Fumariaceæ, in *Viola*, Balsaminaceæ, *Pelargonium*, *Tropæolum*, &c. &c.

Fig. 194.

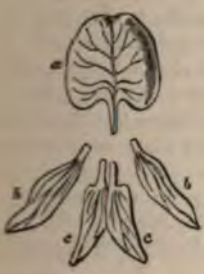


Fig. 193.

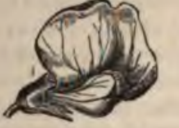


Fig. 195.

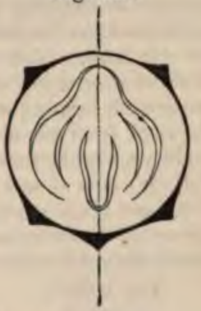


Fig. 193. Papilionaceous corolla.
Fig. 194. The separated petals: *a*, vexillum; *b*, *b*, alæ; *c*, *c*, carina.
Fig. 195. Ground-plan of floral envelopes, showing the æstivation of the petals.

182. The *monopetalous* corolla has a *tube*, *throat*, and *limb* like the monosepalous calyx (§ 174); and similar terms are used to indicate the more common *regular* forms, such as *tubular* (fig. 192), *campanulate* (fig. 196), *funnel-shaped* or *infundibuliform* (fig. 197), *urceolate* (fig. 198), &c., a few others being requisite for the corolla, more especially such as *rotate*, when the tube is extremely short and the limb spreads at a right angle (*Anagallis*), *hypocrateriform* or *salver-shaped* when a similar limb turns off from a long slender tube (*Jasminum*, *Phlox*) (fig. 199), &c.

183. *Irregular* monopetalous corollas often furnish important systematic characters; and several of the forms or classes of forms have special technical names. The *ligulate* corolla is tubular at the base; but disunion soon occurring at one sinus, the limb is turned off to

one side in the shape of a flat riband or strap, on the margin of which occur more or less distinct teeth indicating the five component petals (fig. 200); this is especially found in the ray *florets* (§ 131) of Compositæ: a modification with the tube and limb wider in proportion to the length occurs in Lobeliaceæ. The *labiate* or *bilabiate* corolla of the Labiatæ (fig. 201) is formed by the two upper petals of the limb, which are scarcely at all separated, and stand apart from the three lower or anterior petals, which also are only partially separated, forming a lower lip opposite the upper one and projecting forward from the *throat* of the corolla: sometimes the upper lip is concave, and is then termed *galeate*, or helmet-like; in other cases (*Ajuga*) it is almost abortive.

Fig. 196.

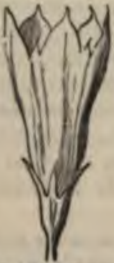


Fig. 197.

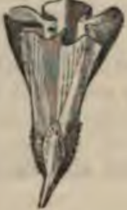


Fig. 198.

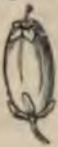


Fig. 199.

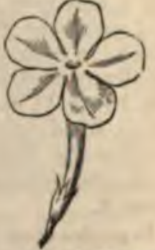


Fig. 196. Campanulate corolla of a Gentian.
Fig. 197. Funnel-shaped corolla of *Convolvulus*.
Fig. 198. Urceolate corolla of a Heath.
Fig. 199. Hypocrateriform corolla of *Phlox*

Almost every modification of this form occurs in the Labiatæ, approaching to an almost regular tubular corolla in *Mentha*. This form occurs also in the florets of some Compositæ and in those of various Dip-

Fig. 200.

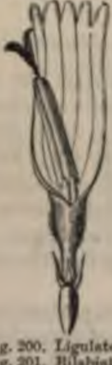


Fig. 201.

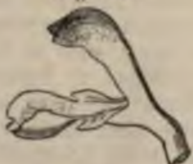


Fig. 202.

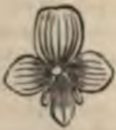


Fig. 200. Ligulate floret of Compositæ.
Fig. 201. Bilabiate corolla of *Salvia*.
Fig. 202. Corolla of *Veronica*, bilabiate in structure, but the segments spreading like a rotate corolla.

aceæ, where, however, the upper lip is 3-lobed and the lower 2-lobed; in the Honysuckle the upper lip contains four petals, and the lower is formed by a solitary one. *Veronica* has an irregular corolla intermediate between *bilabiate* and *rotate* (fig. 202).

184. The *personate* or *mask-like* corolla is rather indefinite in form: the type of it occurs in *Antirrhinum* (fig. 203), which approaches the *labiate* form; but the throat is closed by a gibbous projection (forming the *palate*), giving the front view the appearance of a mask with a broad-lipped mouth.

This is accompanied by a similar *gibbous* condition of the base of the tube in *Antirrhinum*, and by a spur in the same situation in *Linaria*. Aberrant forms of this type occur in *Calceolaria, Utricularia* (fig. 204); and it runs into the *labiate* form by such corollas as those of *Melampyrum* &c., becoming tubular in *Digitalis*. Forms allied to this occur commonly in Bignoniaceæ, Gesneraceæ, Acanthaceæ, &c.

185. When the throat of a bilabiate, or irregularly lobed tubular corolla is widely opened, it is called *ringent* or gaping.

186. Petals when distinct sometimes exhibit appendages on the inner face which have been interpreted as stipulary, as in *Lychnis* (fig. 188); in *Ranunculus* we find a minute *scale* at the base, and in *Parnassia* a largish scale, simple or divided, and of glandular character. In monopetalous corollas we often find a *circle* of *scales* in the throat, either free or confluent into what is called a *coronet* (*corona*), sometimes developed so far as to produce a long tube projecting from the throat. In other cases there is simply a ring of hairs in the throat (*Mentha* &c.).

In most cases the scales are opposite to the lobes of the corolla (fig. 205), rarely alternate and opposite to the sinuses.

Examples of circles of scales in the throat occur especially in the

Fig. 203.

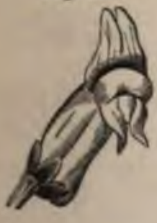


Fig. 205.

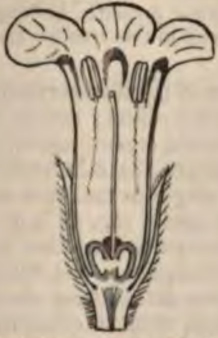


Fig. 204.

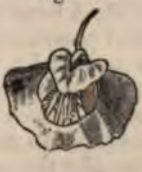


Fig. 203. Personate corolla of *Antirrhinum*. Fig. 204. Personate corolla of *Utricularia*.
Fig. 205. Section of a flower of a Boraginaceous plant, showing scales in the throat, between the stamens.

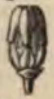
Boraginaceæ (*Myosotis*, *Symphytum*, &c.), in *Cuscuta*, &c. In *Narcissus poëticus* and other species the corona is a complete ring, while in *N. pseudo-narcissus* (the Daffodil) it forms the deep yellow tube projecting from the centre. Some authors attribute these structures to *chorisis*, and derive the explanation of opposite stamens from them (§ 149); others regard them as representing a circle of regular stamens in an abortive condition; and the alternate scales of *Samolus* may represent an abortive circle of stamens, as this would restore the symmetry of the flower. Usually they are mere outgrowths from the petals, formed by *enation* at a late stage of development.

These structures, by a confusion of terms, have been called *nectaries* and nectariferous scales (§ 179). The terms *scale* and *coronet* are more exact and convenient.

187. The duration of the corolla is *caducous*, *deciduous*, or *persistent*, like the calyx. Occasionally it falls away in part by a circular slit, as in *Orobanche* and *Rhinanthus*.

In *Vitis* the caducous *corolla* separates from the receptacle at the bases of the petals, which cohere above and fall off like a little star when the flower opens (fig. 206). The corolla is mostly *deciduous*; it is persistent in *Campanula*.

Fig. 206.



Opening flower of the Vine. The petals, cohering by their tips, fall off in one star-shaped piece.

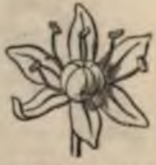
## *The Perianth.*

188. This has been defined as consisting of the floral envelopes as a whole when composed of two circles of similar organs, or of one circle (a calyx only) when the general character of the Order is Monochlamydeous.

Attempts are sometimes made, in cases where a single circle only exists, to distinguish whether this should be called a calyx or a corolla; if a single circle of stamens stands opposite to the lobes, we may suppose a corolla of alternating petals to be suppressed; if the stamens alternate with the lobes of a simple perianth, nothing would appear to be suppressed between them, and in this case we may suppose that it is really the calyx suppressed.

189. A large number of the Monocotyledonous orders possess a *petaloid perianth*; that is, there are two circles of petaloid organs, which, from their resemblance, or their actual coherence, have the appearance of a single hexamerous whorl. This perianth may be *regular* (fig. 207) or *irregular*, like the normal calyx and corolla; it may be *polyphyllous* or *monophyllous*; and the outer circle may differ to some extent from the inner in form, size, and colour, without other irregularity. The forms are described by the same terms as those used for the calyx and corolla (§§ 175 & 182).

Fig. 207.



Regular 6-merous petaloid perianth of *Allium*.

We have a regular polyphyllous perianth in the Tulip and Lily, a regular monophyllous perianth in *Hemerocallis*, *Convallaria*, *Tamus*, &c., a regular polyphyllous perianth with unlike circles in *Iris*, and irregular polyphyllous perianths in Zingiberaceæ, Orchidaceæ, &c.

190. The irregular perianth of Orchidaceæ (figs. 208 & 209) requires especial mention, as the Order is very large, and the characters of the perianth peculiar. There are three outer organs (*a*, *a*, *a*), more or less alike, and usually smaller than the inner; of the inner, the lateral (*b*, *b*) are smaller than the posterior (*b*′), called the lip (or *labellum*), which is often excessively developed, and even divided into regions which receive separate names; in many of our native Orchids it possesses a spur (fig. 208 *b**).

191. The perianth of the Palms, of Juncaceæ (fig. 210), and other Monocotyledons is composed of scale-like, fleshy or membranous organs, either free or confluent, approaching to the condition found in the Glumiferæ.

Fig. 208.

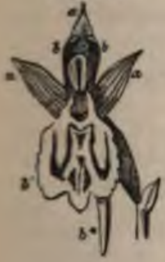


Fig. 209.

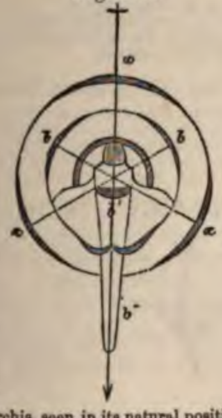


Fig. 210.

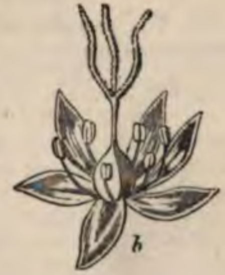


Fig. 208. Flower of an Orchis, seen in its natural position, where, owing to the twisting of the inferior ovary, the anterior part is above and the posterior below. *a*, *a*, *a*, represent sepals; *b*, *b*, the lateral petals; *b*′, the labellum, prolonged behind at the base into a spur, *b**.

Fig. 209. Ground-plan of the flower, with the same references.

Fig. 210. Flower of *Luzula*: *b*, the 6-merous scaly perianth.

192. The perianth of the Monochlamydeous Dicotyledons is very varied in form, texture, and colour. It may be *monophyllous* or *polyphyllous*, and then *regular* (fig. 211) or *irregular* (fig. 212), and, moreover, *petaloid* or *sepaloid*. It is reduced to the lowest state in the Poplar (fig. 213), where it is a mere membranous cup; and it is absent in the allied genus *Salix*, as also in the Ash (fig. 214).

A monophyllous, coloured, regular perianth exists in Thymelaceæ (*Daphne*); the dull-coloured monophyllous perianth of *Aristolochia* is irregular (fig. 212). The monophyllous sepaloid perianths of *Ulmus* and *Castanea* (figs. 215, 216) &c. are regular; the polyphyllous sepaloid perianth of Urticaceæ is also regular. In *Polygonum*, the regular monophyllous perianth is partially petaloid, while, in the same Order, *Rumex* and *Rheum* have a double circle of unequal, wholly sepaloid organs.

Fig. 211.

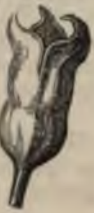


Fig. 213.

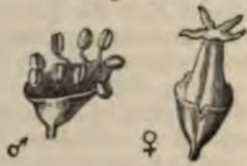


Fig. 212.

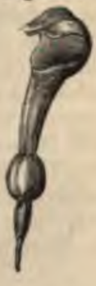


Fig. 211. Regular perianth of *Asarum*.
Fig. 212. Irregular perianth of *Aristolochia Clematitis*.
Fig. 213. Flower of the Poplar: ♂, from a male catkin; ♀, from a female catkin; each with an abortive perianth.

193. The perianth of the Glumiferous Monocotyledons requires special mention.

Fig. 215.

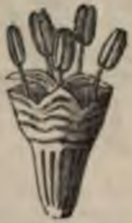


Fig. 214.

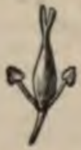


Fig. 216.

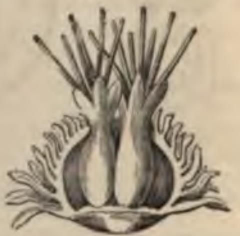


Fig. 214. Naked flower of the Ash (*Fraxinus excelsior*).
Fig. 215. Flower of the Elm (*Ulmus*), with a regular 5-toothed perianth.
Fig. 216. Involucre or young cupule of the Chestnut (*Castanea vesca*), with two female flowers, each having a regular perianth.

In the Grasses, as already mentioned (§ 126), the flowers are borne in *spikelets*, associated in spikes, or panicles. A spikelet of the Oat, for example (fig. 217), exhibits at its base a pair of green membranous scales, the *glumes* (*a*, *a*), more or less enclosing all the inner parts: these are regarded as bracts, forming a kind of involucre; and within them are found one, two, or more flowers. The flowers succeed one another alternately on a *rachis*; and each is composed of two scales resembling the glumes, but smaller, called *pales* (*paleæ* or *glumellæ*) (figs. 217–219, *b*, *b′*): the outer one of these is the larger; but the inner one is forked at the top, and often has two distinct principal ribs; hence it is regarded as composed of two confluent parts, making, with the outer free one, three sepals. These pales or calycine scales often bear a projecting bristle (*awn, arista*) at the top or on the back (fig. 218 *b**). Within the pales (fig. 219) occur two, or in some Grasses three, little hypogynous scales (*lodiculæ*, *x*, *x*), regarded as abortive petals; and to these succeed the stamens and pistil.

Fig. 217.

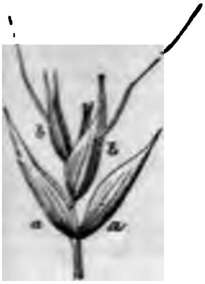


Fig. 219.

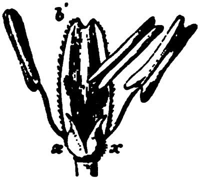


Fig. 218.

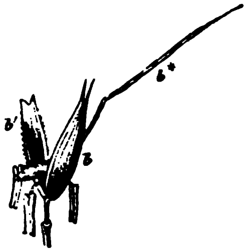


Fig. 217. Spikelet of the Oat: *a*, *a*, glumes: *b*, *b*, the outer pales of the two florets.
Fig. 218. One floret detached and opened: *b*, the outer pale (with an awn *b**); *b'*, the inner pale.
Fig. 219. The same, magnified, with the outer pale removed: *b*, the inner (double) pale; *x*, *x*, the *lodiculæ* or hypogynous scales representing the petals, within which are the three stamens and the ovary, with its double feathered stigma.

Some authors regard the pales (especially the outer one) as well as the glumes as bracts. The hypogynous scales are three in number in *Stipa*, restoring the symmetry. The upper glume is sometimes abortive, as in *Lolium*, while in *Nardus* both are absent. In *Alopecurus* only one pale is developed. The spikelet often contains one or more imperfect flowers.

194. The perianth of Cyperaceæ, where it exists, presents a still simpler condition, analogous to that in the Amentiferous Dicoty-

Fig. 220.

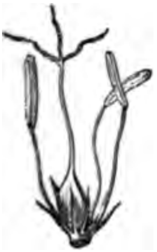


Fig. 221.

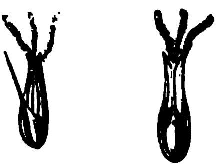


Fig. 220. Flower of *Scirpus*, the essential organs surrounded by a circle of bristles.
Fig. 221. Female flower of *Carex*: *a*, the *perigynium*, or perianth, in the axil of a bract; *b*, the tubular *perigynium* cut open vertically, to show how it surrounds the pistil.

ledons, and in some cases is abortive. In *Scirpus* (fig. 220) it consists of a circle of bristles; in *Eriophorum* it is a tuft of hairs, which grow out into a "lock" of cotton as the fruit ripens. In *Carex* (fig. 221) there is an urceolate or inflated tubular perianth (*perigynium* or *utriculus*) surrounding the pistil of the fertile or female flower, which stands in the axil of a bract; *Cyperus*, *Cladium*, &c. have the essential organs naked in the axil of a bract.

## **Sect. 9.** THE ESSENTIAL ORGANS OF FLOWERS.

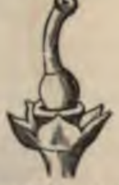
195. The essential organs of flowers consist of *stamens* and *pistils*, both of which are present in *perfect* flowers, although these latter may be *incomplete*, from the absence of floral envelopes. In *diclinous* or *unisexual* flowers the stamens or pistils exist alone, and the flowers are consequently *imperfect*.

As the stamen possesses a determinate physiological function, there can be no organs *physiologically* intermediate between petals and stamens; but organs *morphologically* intermediate occur, not only normally, as in the flowers of *Nymphæa* (§ 140), but such structures are very common in monstrous double flowers, bearing anthers or polliniferous lobes upon the borders of petals. The morphological connexion is also kept up by the existence of sterile filaments or stamen-stalks, which, like the filaments of perfect stamens, may exhibit a *petaloid* character.

Still less can there be any *physiological* intermediates between stamens and pistils, as they represent the distinct sexes; but here, again, morphologically, connexion is occasionally shown in monstrous flowers, where imperfect organs present themselves, partaking of the outward characters both of stamens, and carpels.

Abortive organs, referable either to the corolline or the staminal circles or excrescences therefrom, have been already referred to (§ 186); but it is desirable to notice more particularly the conditions of those structures which are commonly described under the name of *disk*. The simplest state is that of one or more glandular papillæ, upon the receptacle, as in the Cruciferæ (§ 149). In the Crassulaceæ (*Sedum*, *Sempervivum*) we find a circle of glandular bodies outside the carpels and between these and the stamens. In *Cobæa*, the Vine, and other flowers, there is a five-lobed hypogynous disk, the stamens being inserted outside or between the lobes. In *Citrus* (fig. 222) the disk forms a perfect ring round the ovary. In *Gaultheria* there is a double circle of scales between the stamens and the ovary. On the other hand, in *Vinca* there are two glands, alternating with the two carpels of the ovary. The study of these structures is very interesting, in regard to the reduction of irregular flowers to regular types. Some of the structures are rudimentary petals or stamens; and in other cases they are referable to developments of the receptacle itself, constituting what DeCandolle named the *torus* (§ 160).

Fig. 222.



Flower of *Citrus* with the petals and stamens removed, showing the annular disk surrounding the ovary.

196. The calyx and corolla having distinctive collective names, analogous terms are sometimes used for the assemblages of stamens and pistils of a flower: the stamens collectively constitute the *andrœcium*; the combination of carpellary organs forms the *gynœcium.*

### *The Stamens.*

197. The essential character of a *stamen* is, that it is that organ in which are formed the *pollen-grains,* the bodies by means of which the fertilization of the ovules is effected. A completely developed stamen (fig. 223) exhibits two principal regions, the *filament* or stalk (*a*), corresponding to the petiole of a leaf, and the *anther* (*b*), corresponding to the blade of a leaf—which is a hollow body containing the pollen, and is therefore the only essential part of the organ: the filament may be wanting or merely rudimentary; and the anther then remains *sessile,* like a leaf-blade when the petiole is not developed. The normal position of the stamens is between the petals and the pistil; each stamen, under ordinary circumstances, intervenes between two petals or is alternate with them, and therefore superposed or opposite to a sepal.

The base of the filament, or of the so-called sessile anther, is usually *articulated* to the receptacle when these organs are *free* (§ 157); but this condition is more or less disguised when the stamens are adherent to the calyx, corolla, or ovary.

198. Sterile filaments, *i. e.* such as are devoid of anthers, occur in many flowers in regular circles (§ 152); and not unfrequently one or more stamens exist in this condition in unsymmetrical flowers. Sometimes these *staminodia* are reduced to mere *scales,* as in the odd stamen of *Scrophularia* (fig. 224), or to glandular papillæ, as in the flowers of many Cruciferæ.

199. The *filament,* in its usual condition, is a slender thread-like stalk to the anther, and in this state is termed *filiform.* Sometimes

Fig. 223.

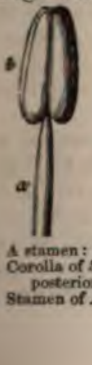


Fig. 224.

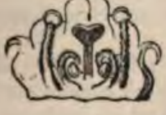


Fig. 225.

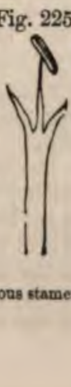


Fig. 223. A stamen: *a*, the filament; *b*, the anther.
Fig. 224. Corolla of *Scrophularia* laid open, showing the four didynamous stamens and the posterior barren one, or staminode.
Fig. 225. Stamen of *Allium*, with a trifid filament.

it is almost hair-like, and incapable of supporting the weight of the anther, when it is *capillary*, as in the Grasses; while it is still more frequently thick at the base, diminishing gradually upwards, so as to become *awl-shaped* or *subulate*. In a few instances (*Urtica*) it is *moniliform*, or like a row of beads. In other cases it is more or less expanded into a *petaloid* condition, as in *Erodium*; in *Campanula* it is expanded in this manner at the base. *Ornithogalum* has the filament *dilated* in this way throughout. The dilated filament sometimes exhibits *divisions*: in *Crambe* it is forked at the summit, the anther standing on one point; in *Allium* (fig. 225), *Alyssum calycinum*, *Ornithogalum nutans*, &c. the filament terminates in three teeth, the middle one bearing the anther; and in *Allium sativum* one of the lateral teeth forms a kind of tendril.

In some plants, as in Mallows, some Myrtaceæ, *Hypericum*, &c., the stamens are very numerous and are arranged in fascicles. The study of the development of these flowers shows that in most cases these fascicles are originally single organs, which become subsequently divided, or rather branched, so that the fascicle of stamens in such a case may be compared to the compound leaf.

200. Appendages of other kinds are also met with, such as a pair of *glandular processes*, standing like stipules near the base, in Lauraceæ (fig. 233), a single *spur* in Rosemary; while in *Borago* the filament appears to arise on the face of a scale-like body, and in *Simaba* and *Larrea* it stands at the back of an analogous scale.

The scale-like organs situated at the base of filaments, or connected with fascicles of stamens (*Tiliaceæ*), are by some regarded as furnishing evidence for the doctrine of *chorisis* (§ 149); but they are more probably merely barren lobes of compound stamens.

201. The *anther* has a typical form, which is subject to very great modification in different cases. A *regular* anther (fig. 223, *b*) is an oblong body, divided perpendicularly into two *lobes*; the division is usually marked by a furrow on the *face*, and a ridge on the *back* (or *dorsum*). The central region, which is solid and represents the midrib of a leaf, is called the *connective*; the *lobes* are hollow dilatations of the lamina, and contain the *pollen*. At each border, usually rather toward the *face*, is a vertical line, called the *suture*, indicating the place where one class of anthers split open to discharge the pollen.

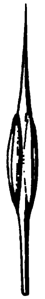
202. The anther is attached to the filament in several ways: if the filament runs directly without interruption into the base of the connective, like the stalk of an ordinary leaf, it is said to be *innate* or *basifixed*; if the filament runs up the back of the anther as it were, so that the latter is more or less free at the base, the anther is *adnate* or *dorsifixed*; if the filament is attached by a slender apex to about the middle of the back of the anther, the latter is *versatile*.

In the Tulip, the capillary point of the anther runs up into a conical pit in the base of the connective.

**203.** The modifications of the anther result from various causes—from development of the connective, from the presence of appendages, from variation of form of the anther-lobes, and from special conditions of the internal cells; and there are also important differences in the manner of bursting, or *dehiscence*, for the discharge of the pollen.

**204.** The *connective* is normally a solid rib, running up the middle of the anther. If the lobes of the anther extend upward or downward beyond it, the summit or base of the anther (or both) becomes *emarginate*. On the other hand, the summit of the connective is prolonged in a membranous form in *Viola*, and also in the Compositæ. In *Paris* (fig. 226) the apex is lengthened into a point, also in *Asarum*, *Magnolia*, &c.; in *Xylopia* into a fleshy mass; in the Oleanders into a feathered process, &c. In two of the stamens of *Viola* the base of the connective has petaloid spur-like appendages; and still more remarkable states occur in the Melastomaceæ.

Fig. 226.



Stamen of *Paris quadrifolia.*

At other times the connective expands transversely, so that the lobes become more or less separated; in such cases it may be *ovate*, *orbicular*, &c. (*Melissa*, the Lime-tree, &c.). This is especially the case with the lower part; and examples may be found illustrating this point, forming a series from the state where the bases of the lobes are but slightly separated, to that in which they are inclined together at the summit at an angle of 45° (*Vitex*); or, further, the bases are carried out and up till they are horizontal, as in *Stachys*,

Fig. 228.

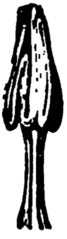


Fig. 227.

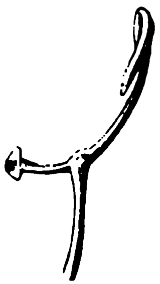


Fig. 229.

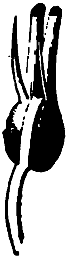


Fig. 227. Stamen of *Salvia officinalis*, with a half-anther containing pollen and the other half barren, separated by the bifurcation of the connective from the summit of the filament.

Fig. 228. Group of stamens with sinuate anthers, of the male flower of a Gourd.

Fig. 229. Stamen of *Vaccinium uliginosum.*

*Prunella*, &c.; while in other instances this goes so far that the connective grows out into two distinct arms from the summit of the filament, bearing the solitary anther-cells at the tips: in *Salvia* (fig. 227) one of the lobes is abortive, and represented by a petaloid plate.

205. The *lobes* of the anther are commonly oblong; in the Grasses they are *linear*; but they vary with the form of the connective, and are sometimes *lunate* or *reniform*. In the Cucurbitaceæ they are remarkably convoluted (*sinuate*) into a flat scroll-like form (fig. 228). Not unfrequently they are attenuated upwards into free points, as in *Vaccinium* (fig. 229); in the Melastomaceæ the two lobes become confluent into a tubular process at the summit; while appendages are occasionally met with at the bases of the lobes, as in *Erica* (fig. 230), &c.

206. The lobes of most anthers exhibit internally four *cells* (or *loculi*) in the early stages of development, each lobe being divided into two by the *septum* extending from the connective to the suture (fig. 231). The septum is more or less destroyed during the maturation of the pollen in most cases, leaving the anther *two-celled*, or *bilocular* (fig. 232). In some cases the internal substance of the connective is likewise absorbed, producing a true *unilocular* anther, as in *Alchemilla* and in Malvaceæ. In other cases the four cells are retained perfect, as in the *quadrilocular* anthers of *Butomus*, where they are parallel, and of some Lauraceæ, where they become *oblique* so that the summits are all turned towards the face. The *dimidiate* unilocular anthers of *Gomphrena* and *Salvia* are so called from being only halves of anthers in which one lobe is abortive or suppressed. Anomalous one-celled anthers occur in *Polygala*. The unilocular

Fig. 230.

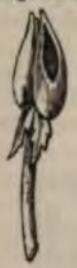


Fig. 231.

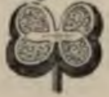


Fig. 232.

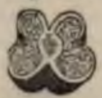


Fig. 233.

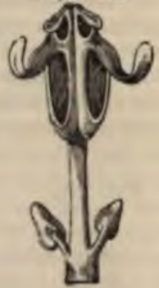


Fig. 230. Stamen of *Erica cinerea*.
Fig. 231. Section of an anther, its two lobes still divided into two cells by the *septa* reaching from the connective to the *sutures*.
Fig. 232. Section of a bilocular anther (the septa have been absorbed).
Fig. 233. Stamen of *Laurus Persea*, having a 4-celled anther with opercular dehiscence, and two lobules at the base of the filament.

lateral anthers of the diadelphous stamens of Fumariaceæ are *dimidiate*.

207. When the anthers are mature, the cells or loculi open and discharge the pollen. This *dehiscence* takes place in different ways; it may be *sutural*, *porous*, or *opercular*.

*Sutural* dehiscence is the opening of the walls by splitting down vertically at the sutures, and turning back like folding doors; this is the more frequent case. A transverse slit is formed in the unilocular anther of *Alchemilla*, in *Lavandula*, and in *Lemna*.

*Porous* dehiscence is where definite orifices are formed at some point of the wall of the loculus, as at or near the summit in *Solanum*, Ericaceæ (figs. 229, 230), &c.

*Opercular* dehiscence results from the partial separation of a portion of the wall of the loculus, in the form of a kind of lid, as in the Berberry, where the front of each cell splits off at the sides and base, and turns back as if hinged at the top. In the Lauraceæ (fig. 233) we find either two or four little lids of this kind, opening the two or four cells of the anthers.

208. The stamens of the Gymnospermia present remarkable conditions, which require separate notice.

Among the Coniferæ, the stamens of *Pinus* constitute the entire male flowers, and are conjoined into male cones, each anther forming a scale of the cone; they are bract-like plates, bearing on the lower face two parallel anther-lobes (bursting longitudinally or irregularly), beyond which the connective extends more or less as a scale-like process. In *Cupressus* the form of the anther is excentrically *peltate* (§ 89), the lobes, three or four in number, standing under the overhanging connective; and it is similar in *Juniperus* and *Thuja*. In *Taxus* the *peltate* connective is more symmetrical, and radiately grooved above, having from three to eight vertical anther-lobes beneath: some authors regard this as a group of monadelphous stamens.

In the Cycadaceæ, where the anthers are scattered in large numbers over the lower face of the scales of the male cones, they occur mostly in the form of groups of four simple anther-lobes, with longitudinal dehiscence and arranged in the form of a cross. These are mostly described as parcels of unilocular anthers.

209. The stamens, taken collectively, present a number of characters, which have received technical names. The number of stamens in a flower is indicated by the terms *mon-androus*, *di-androus*, &c.; when more than twelve exist, the term *poly-androus* is employed. When the number of the stamens is equal to, or some multiple of, the number of petals in the corolla, &c., the flower is *isostemonous*; when the number is different (as in Scrophulariaceæ &c.) the flower is *anisostemonous*.

210. Two cases of inequality of length of the filaments are

distinctly named, viz. the *didynamous* condition (figs. 234 & 235), when there are two pairs of stamens, one pair longer than the other, characteristic of many irregular Monopetalous flowers (Labiatæ, Scrophulariaceæ, &c.), and *tetradynamous* (fig. 236), when there are four long stamens and two short ones, characteristic of the Cruciferæ.

211. The term *included* is employed to denote that the stamens do not reach beyond the corolla; *exserted*, that they are protruded from it; while *declinate* means that the exserted stamens are all curved over to one side.

212. The stamens are subject to apparent confluence or cohesion, like the other organs (§ 154). If the filaments are only partially separated so that they form a tube surrounding the style (or a

Fig. 234.

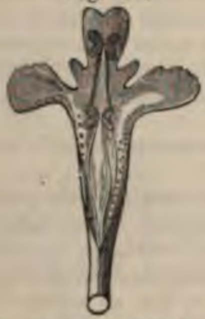


Fig. 236.

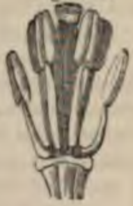


Fig. 235.

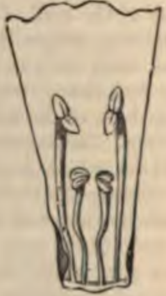


Fig. 234. Corolla of *Glechoma*, laid open to show the didynamous stamens.
Fig. 235. Corolla of *Digitalis*, laid open to show the didynamous stamens.
Fig. 236. Tetradynamous stamens of the Wallflower surrounding the pistil, the floral envelopes being removed.

Fig. 237.

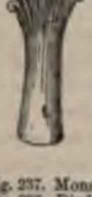


Fig. 238.

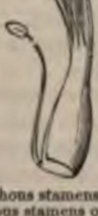


Fig. 239.

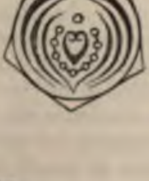


Fig. 240.

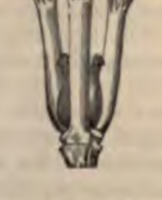


Fig. 237. Monadelphous stamens of *Malva*.
Fig. 238. Diadelphous stamens of Leguminosæ.
Fig. 239. Ground-plan of a Papilionaceous flower with diadelphous stamens (the little circles round the solitary carpel).
Fig. 240. Triadelphous or polyadelphous stamens of *Hypericum ægyptiacum*.

column in a staminate flower of a diclinous plant) (fig. 228), the stamens are *monadelphous* (fig. 237), as in Malvaceæ, *Camellia*, &c. In Fumariaceæ they are coherent into two equal parcels, while in many Leguminosæ, of ten stamens, nine are united together and one free; these states are called *diadelphous* (figs. 238 & 239). In Hypericaceæ we have *triadelphous* (fig. 240) and *pentadelphous* states; but these, as also the state in Aurantiaceæ and various Myrtaceæ, are generally denominated *polyadelphous* (see § 199, compound stamens).

213. *Syngenesious* signifies that the filaments are free, but the anthers coherent (fig. 241), as in Compositæ and Lobeliaceæ. *Gynandrous* indicates confluence of, or want of separation between, stamens and pistils, such as occurs in Orchidaceæ, Asclepiadaceæ, *Aristolochia*, &c. (fig. 242). These terms, together with those descriptive of *adhesion*, *perigynous*, *epigynous*, &c., have already been explained (§ 157), as also the meaning of the words *monœcious*, *diœcious*, &c. (§ 151).

214. Usually what is called the *face* of the stamen is turned inwards toward the ovary, and it is then said to be *introrse*; but sometimes the reverse state exists, and the face is turned towards the floral envelopes, as in *Ranunculus*, *Colchicum*, &c., when the stamens are termed *extrorse*.

Fig. 241.

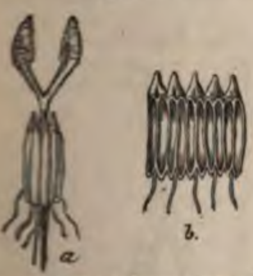


Fig. 242.

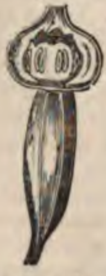


Fig. 243.

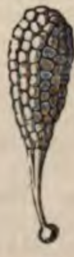


Fig. 241. Syngenesious stamens of Compositæ: *a*, the anthers surrounding the style as a sheath; *b*, the anthers removed and spread out, showing the free filaments.

Fig. 242. Section of the lower part of the perianth of *Aristolochia*, seated on the inferior ovary. In the cavity of the perianth is seen the style, with the adherent anthers upon its sides.

Fig. 243. Clavate pollen-mass of *Orchis*, prolonged below into a *caudicle*, by which it attaches itself to the *rostellum* of the stigma.

215. The *Pollen*, discharged from the anthers, consists in almost all cases of a fine powder composed of microscopic vesicles; the form and appearance of the grains vary much, and will be spoken of hereafter. The pollen of the Asclepiadaceæ and Orchidaceæ, however, has a great peculiarity, in remaining permanently coherent

into masses, often of a waxy character. In Orchidaceæ the *pollen-masses*, or *pollinia*, are either single in each loculus of the anther (as they are in Asclepiadaceæ), and then often furnished, as in *Orchis* &c., with a stalk-like process, called the *caudicle* (fig. 243), terminating in a gland-like base (*retinaculum*), by which they readily adhere to the stigma or to foreign bodies, such as insects; or the *pollinia* are two or four in each loculus, and devoid of a caudicle; sometimes the *pollinia* are numerous, and form merely a loose granular mass.

The external characters of the pollen-grains, their structure, and subsequent history will be treated of in the Third Part of this work, as they belong to the microscopic anatomy and the Physiology of Plants. The form of the pollen-grains is generally constant in the same plant; but great variations are often found within the limits of Natural Orders, so that, excepting the Orchidaceæ and Asclepiadaceæ, and a few other groups, they do not afford any very useful characters in Systematic Botany.

### *The Pistil.*

216. The central essential organs of flowers, composing the *pistil*, consist, like the outer parts, of modified leaves; these constituent leaves are called *carpels*. The peculiar character of a carpel is, that it produces *ovules*, the rudiments of the seeds—usually upon the margins, but occasionally on other parts of the internal surface. In the Gymnospermia these ovules are developed upon the edges or surface of expanded carpels. In the Angiospermia, comprehending the great majority of Flowering plants, the carpels are folded up, either singly (fig. 244) or collectively, with the margins turned in so as to place the ovules in the interior of a hollow case. The case thus formed, enclosing the *ovules*, is called the *ovary* (figs. 224 & 225, *a*, *a'*); the upper part of the carpel is frequently attenuated into a slender column called the *style* (*c*), at the extremity of which is a terminal glandular orifice or *stigma* (*b*, *b*), the borders of which are often more or less thickened or developed into processes of various kinds. Sometimes the *stylar* prolongation does not exist; and then the *stigma* is *sessile* upon the *ovary*.

Fig. 244. Fig. 245.

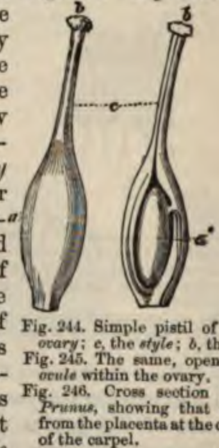


Fig. 246.

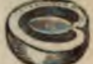


Fig. 244. Simple pistil of *Prunus*: *a*, the *ovary*; *c*, the *style*; *b*, the *stigma*.
Fig. 245. The same, opened, to show the *ovule* within the ovary.
Fig. 246. Cross section of the pistil of *Prunus*, showing that the ovule arises from the placenta at the confluent margins of the carpel.

The pistils are undoubtedly formed of carpels (carpellary leaves) in most instances. Some writers do, indeed, consider them to be formed in certain families by an expansion of the receptacle or axis of the flower; but it is the general opinion that the carpels in such cases are imbedded within the hollow receptacle.

The foundations of the carpellary theory, and of the doctrine that the carpels are metamorphosed leaves, rest upon a very wide basis. The following observations include examples of some of the most important classes of proofs:—1. The carpel ordinarily possesses more of the character of a true leaf, as regards texture and colour, than the stamens or petals—approaching to the sepals, which we have seen to pass insensibly through the bracts (§ 140) into ordinary leaves. The resemblance is sometimes heightened during the development of the fruit, as we see in the legumes of some species of *Cassia*, and still more in the bladder-like pod of *Colutea*. 2. Abundant examples exist of the substitution of petals for stamens and pistils in abnormal flowers; and an almost equally common monstrosity consists in the substitution of isolated stunted green leaves for the carpels. In the Double Cherry, cultivated in shrubberies for the sake of its blossom, the stamens are generally replaced by petals, while the centre of the flower is mostly occupied by a pair of green leaves. (The single, fertile Cherry frequently has two pistils developed instead of one.) In a common monstrosity of the White Clover, the pod is usually replaced by a more or less perfect green leaf; the same occurs in garden Roses, where tufts of green leaves replace the pistils; and, in fact, examples of this kind are very abundant. 3. The more or less stunted green leaves which represent the carpels in the above-mentioned monsters frequently exhibit on their margins structures varying in character from almost perfect rudiments of ovules to cellular papillæ and leafy lobules. This is observed in the monstrous Clover, and has been especially remarked also in monstrous flowers of cultivated (forced) Tulips, of various Cruciferæ, Ranunculaceæ, Scrophulariaceæ, &c. The abnormal conditions in these cases are analogous to the normal condition in Coniferæ and Cycadeæ, the Gymnosperms, where the ovules are always naked on open carpels. 4. The production of ovules on the margins of carpels is analogous to what is seen in the development of *adventitious buds* on vegetative leaves, as in *Bryophyllum* &c. Such buds, however, occur sometimes on the upper surface of leaves; and we find some carpels, as in *Nymphæa*, *Butomus*, &c., with ovules developed more or less extensively over the internal face. 5. The disposition or arrangement of the vascular bundles is that of the leaf, not that of the branch. The structure and mode of growth generally are those of the leaf and not of the branch.

217. The region of the carpel whence the ovules arise is called the *placenta*; and when in Angiospermous flowers the placentas are clearly and distinctly marginal, they must of course be *double*, from the meeting of the two edges; the same is true of the *stigmatic surfaces*. The line of union of the margins of carpels constitutes the *ventral suture*; the line corresponding to the midrib of the carpellary leaf is the *dorsal suture*.

An excellent example of a simple typical pistil formed of a single carpel is afforded by the legume of the Leguminosæ; as, for instance, in the

Sweet-pea, where we find the ovary, with a ventral and dorsal suture, narrowed above into a short slender style, terminating in a slightly enlarged stigma. When we open the ovary, in the way it is broken in shelling peas for the table, we find the placentary margins separated at the ventral suture, each carrying away half the ovules, demonstrating clearly the double character of the placenta.

218. Pistils differ extremely in different plants, from dissimilarity in the number, degree and mode of union, and relative development of the different regions of the carpels, to which are added the peculiarities arising from adhesion of the outer circles.

219. The number of carpels is most frequently less than that of the organs in the outer whorls, being very frequently reduced to two, and often to one. On the other hand, multiplication of the number is met with in certain Orders, where the receptacle is generally more or less enlarged to make room for them.

A large portion of the Monopetalous Dicotyledons, with a quinary arrangement of the calyx and corolla, and often of the stamens, have dicarpellary pistils, as Gentianaceæ, Apocynaceæ, Solanaceæ, &c. Leguminosæ with quinary flowers have a solitary carpel. The agreement of the number of carpels with the other organs is almost universal in the ternary flowers of Monocotyledons, as in Liliaceæ, Iridaceæ, Orchidaceæ, &c. Multiplication of carpels is especially frequent in the Ranunculaceæ, Magnoliaceæ, and some other Orders.

220. A most important set of conditions arises from the phenomena of cohesion in the carpellary circle. In the typical pistil above described, and which really exists in Leguminosæ (for instance), the organ, being composed of one carpel only, is *simple*. A carpel may be solitary in a flower, from suppression of the remainder of the circle; or there may be in the same flower several distinct, *i. e.* uncombined carpels, as in Larkspur, Aconite, *Magnolia*, *Ranunculus*, *Fragaria*, &c.; in these cases the term *multiple pistils* is occasionally used, or we may say carpels *distinct*, three, five, or numerous, as the case may be. The term *apocarpous pistil* includes both the solitary carpel and the multiple pistils. In the case of multiple pistils, where the receptacle is flat the carpels are in *whorls*; but if the receptacle is elongated the carpels are arranged *spirally*, as in *Magnolia*.

221. Where, as very frequently happens, the carpels cohere together, as the stamens do in the condition called monadelphous, a *syncarpous* or *compound pistil* is formed; and as the carpels occupy the apex of the receptacle, they do not form an open organ, like the tube of filaments in *Malva*, for example, but a closed case, appearing externally like a solid body, mostly with ridges and grooves on the outside, indicating its compound nature.

The union varies very much in degree: even in multiple pistils we find the carpels sometimes cohering strongly while young, and separating only as the seeds ripen; and in true compound pistils the union does not always extend to the summit of the ovarian region, as we observe in the Saxifragaceæ, where the apices of the ovaries diverge. More frequently the ovarian regions are firmly coherent; and then the *styles* may be wholly free—Pink, *Silene* (fig. 174), *Hypericum*, &c.,—or united part of the way up—as in some Malvaceæ (fig. 247),—or entirely, but with the stigmas distinct (as in *Geranium*, &c.); or the stigmas may also be confluent (Primulaceæ, Solanaceæ, &c.). Sometimes, however, the styles or stigmas exhibit the reverse condition, and are split into two parts, as in the styles of *Drosera*, *Euphorbia*, &c.

222. The conditions arising from adhesion have been referred to already, under the names of *superior* or *inferior calyx* or *ovary* (§ 158). They are always associated with cohesion when more than one carpel exists. The styles are free when the ovary is inferior, either coherent, as in Iridaceæ (fig. 260), or distinct, as in the Umbelliferæ (fig. 171) and Rubiaceæ. In *Saxifraga*, and in some other cases, the ovary is half-inferior. When the stamens are consolidated with the pistil, the *gynandrous* condition is produced. In Orchidaceæ the filaments are inseparable from the style, forming a *column* surmounting the ovary; in Asclepiadaceæ the anthers adhere to the summit of the free compound style; in Aristolochiaceæ the filaments adhere to the base of the compound style (fig. 242).

223. Compound pistils are sometimes smooth and even on the outside, showing no sign of their compound nature, as in *Primula* &c.; in other cases they exhibit more or less deep furrows at the lines of junction, sometimes dividing them into lobes. But the internal structure of the ovary generally indicates the number of carpels entering into its composition very plainly.

Fig. 247.

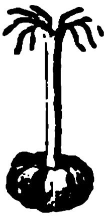


Fig. 248.

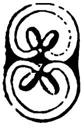


Fig. 249.

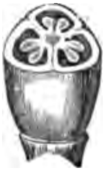


Fig. 250.

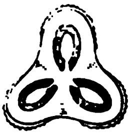
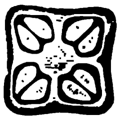


Fig. 251.



Multilocular compound ovaries.

Fig. 247. Ovary, styles, and stigmas of *Malva*. Fig. 249. 3-celled ovary of *Lilium*.
Fig. 248. 2-celled ovary of Scrophulariaceæ. Fig. 250. 3-celled ovary of *Commelyna*.
Fig. 251. 4-celled ovary of *Fuchsia*.

224. When the carpels are firmly and organically united by the surfaces of contact, we obtain the type of a *compound multilocular* or *many-celled ovary* (fig. 248). In these cases the sides of the constituent carpels are folded inwards, so as to meet in the centre,

and thus form partitions between the chambers (*cells* or *loculi*). The placental margins of the infolded carpels are retroflexed, constituting *central* or *axile* placentas. The partitions are called *dissepiments*, and are necessarily double, being composed of the conjoined side-walls of contiguous carpels. In such ovaries the *dorsal* sutures are in the outer wall, while the ventral sutures meet in the centre (fig. 248).

Examples of this kind of ovary are furnished by Liliaceæ (fig. 249) and many other Monocotyledonous orders, by Ericaceæ, Solanaceæ, Scrophulariaceæ, &c. In some cases the ventral sutures and placentas are not directly confluent, but adhere to a central prolongation of the receptacle running up between them, as in Geraniaceæ (fig. 276), &c.

*False* or *spurious dissepiments* occur occasionally both in compound and simple ovaries, consisting of membranes or plates developed from the placenta or from the dorsal suture, and subdividing the originally single cavity formed by individual carpels. Thus in *Linum* the 5-carpellary ovary would have five cells, were it not that a spurious dissepiment extends inwards from the dorsal suture to the placenta in each cell, and divides the ovary into ten cells. In *Astragalus* (fig. 252) the simple ovary is divided by the inflexion of the dorsal suture, and in *Datura Stramonium* a false septum is formed in each of the cells while the seeds are ripening. The *transverse* false septa found in various Leguminous ovaries, such as *Cathartocarpus* &c., are likewise placental developments.

225. If the carpels are not inflexed, but cohere by their contiguous margins, they form a hollow case with only a single cavity; and as the lines of junction of the carpels are on the outer wall, the placentas must stand inside those lines; in this way is formed a *unilocular compound ovary* with *parietal placentas* (figs. 253–255). There are no dissepiments; and the ventral sutures, alternating on the outer walls with the dorsal sutures, are, in such cases, like the placentas within, formed of the confluent margins of two different carpels instead of those of the same carpel.

Fig. 252.

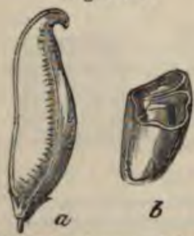


Fig. 253.

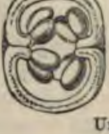


Fig. 254.

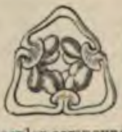
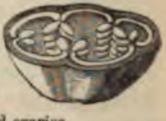


Fig. 255.



Unilocular compound ovaries.

Fig. 252. *a*, legume of *Astragalus*; *b*, cross section, showing a false dissepiment formed by the inflexion of the suture.

Fig. 253. Ovary of Gentianaceæ.
Fig. 254. Ovary of *Viola*.
Fig. 255. Ovary of *Cistus*.

We find almost every possible degree of transition between the *parietal* and the *axile placentas*, according as the placentiferous margins project more or less into the interior of the ovary. True parietal placentas are found in Violaceæ (fig. 254), Resedaceæ, Gentianaceæ (fig. 253), Fumariaceæ, Cistaceæ (fig. 255), Grossulaceæ, &c. In *Papaver* we have the margins turned-in so as nearly to reach the centre (as imperfect dissepiments); in some Hypericaceæ (*H. graveolens*) the originally axile placentas become parietal by separation during the ripening of the fruit, while in Cucurbitaceæ the originally distinctly parietal although greatly inflexed margins ultimately cohere so as to form an axile placenta.

In Cruciferæ we have an anomalous condition, where there are two double parietal placentas, but from the central line of each projects a plate passing across the cavity and forming a kind of spurious septum, called *replum*; so that each cell contains only the two half-placentas formed by its own margins.

226. In some Orders, where the walls are as in the unilocular compound ovaries above described, the placentas are found as a free column or expanded mass in the centre of the common cavity. This forms the *compound unilocular ovary with a free central placenta.* In Primulaceæ, Santalaceæ, and some other Orders, where this kind of placentation occurs, the placentas are free from their very earliest state, and are seen to be direct prolongations of the receptacle within the carpels.

The appearance of a free central placenta is presented in Caryophyllaceæ and some other plants by the obliteration during development of the partitions which, in a young state, pass between the outer walls and the centre of the carpels.

In the opinion of Schleiden and some others, the marginal theory of placentation is erroneous. The placentas are supposed to be in all cases stem-structures, ramified or simple, axillary to the carpels, or forming the terminal bud of the axis or apex of the receptacle, within a cavity either formed by carpels or by a hollowing-out of the end of the receptacle. Thus the solitary ovules in the simple pistils of *Ranunculus*, *Prunus*, *Fragaria*, &c. would be axillary buds of the carpels. The solitary ovule of Plumbaginaceæ, Compositæ, Thymelaceæ, &c. would be the terminal bud of the axis. The free central placenta of Primulaceæ, &c. would be a terminal shoot covered with buds or ovules; and the cases of axile placentas in multilocular ovaries (Liliaceæ, Scrophulariaceæ, &c.) would result from the margins of the carpels turning in and adhering to the central body. Parietal placentas are explained by supposing the terminal shoot to branch out into as many processes as there are placentas, these shoots bearing buds (ovules) and adhering to the internal surface of the carpellary walls.

These views are not much adopted; for while the marginal theory explains most cases very naturally, it may be made to explain free central placentation more satisfactorily than parietal placentation can be explained on the other hypothesis.

227. The placentas have been spoken of as *double*, on account of their origin; where only one ovule exists in a cell, it is assumed that one at least is suppressed; and this other is not unfrequently developed in the Cherry, Almond, &c. (causing the double kernels). In Leguminosæ the double placental base is so narrow that the ovules are placed one over another, and form what appears like a single

line. In Larkspur, Columbine, &c. there is a distinct double row; in many cases each placenta has a double row of ovules; while axile placentas are frequently thickened and enlarged, so as to bear a large collection of ovules, closely packed. In *Papaver* the ovules exist all over the imperfect septa; in *Nymphæa*, all over the sides of the dissepiments, and *not at the margins*; in *Butomus*, all over the inside of the carpels, &c. Where ovules arise from the base of a carpel, either singly or in larger numbers, the placentation is called *basilar*; it is in most cases a slight modification of free central.

228. The *styles* require no particular notice beyond the statements already made, except in regard to their irregular position in some cases. The style is really produced from the apex of the carpel; but in various Rosaceæ, the ovarian part of the structure is so developed that it leaves the style on one side (*lateral*) (*Fragaria*, fig. 256), and sometimes even grows out and up so much that the style, then called *basilar*, seems to arise from the base (*Alchemilla*). In the Boraginaceæ and Labiatæ a similar condition of the styles exists in a compound pistil; the styles in these plants are confluent, and arise as a solitary column from a deep depression in the centre of the 4-lobed ovary, communicating with the cells near the base as in the Rosaceæ referred to. These styles of Labiatæ &c. are called *gynobasic* (fig. 205).

Fig. 256.

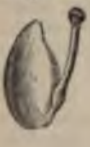


Fig. 257.

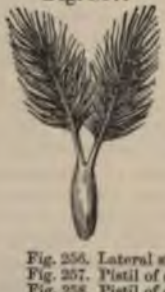


Fig. 258.

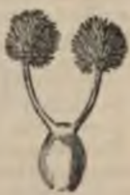


Fig. 259.

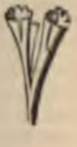


Fig. 256. Lateral style of *Fragaria*.
Fig. 257. Pistil of a Grass, with feathery stigmas.
Fig. 258. Pistil of a Grass, with penicillate stigmas.
Fig. 259. Stigmas of *Crocus*.

229. The *stigma* is either situated at the end of the style or, where this structure is wanting, it is *sessile* on the ovary. Instances of *sessile* stigmas are furnished by the compound pistils of *Papaver* (fig. 262), Nymphæaceæ, &c., where the stigmas form radiating ridges on the top of the flattened ovaries. The elongated stigmatic surfaces on the inner sides of the beak-like points of the simple pistils of *Ranunculus* and allied plants are almost to be called sessile stigmas; and these form a transition to the long stigmatic ridges which extend down the inner sides of the styles of most Caryophyllaceæ. When it is

properly terminal it exhibits a great variety of conditions, both as regards composition and structure.

It has been stated that the styles of compound ovaries are often *distinct*; the stigmas are also often distinct on compound styles, indicating the number of constituent carpels. Moreover these distinct stigmas are occasionally split down into two arms (*stigmata bicruria*), corresponding to the two placentas below; the one-celled ovary of Grasses and Compositæ (fig. 264) bears a two-armed stigma; and the stigmas of the compound ovaries of *Euphorbia* and some *Droseræ* are double the number of the carpels. Sometimes the distinct arms of different carpels cohere, and form stigmas equal in number to the placentas, but alternating with them.

Fig. 260.

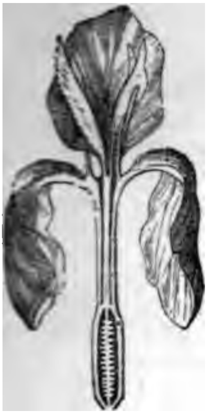


Fig. 262.

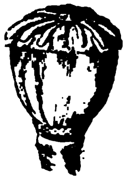


Fig. 261.

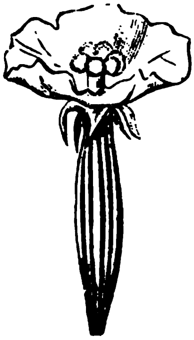


Fig. 260. Vertical section of the flower of *Iris*; the style terminates in petaloid stigmatic lobes.
Fig. 261. Female flower of *Cucumis sativus*, with a lobed stigma.
Fig. 262. Ovary of *Papaver*, with radiate sessile stigmas.

230. Stigmas, simple or compound, when distinct, are either *terminal*, or *lateral*: in the latter case the stigmatic surface is on the ventral side. Their form is generally slender and thread-like, with a glandular stigmatic surface; but in the Grasses the stigmas are feathery (fig. 257) or *penicillate* (fig. 258); in the Iridaceæ they are petaloid (fig. 259), very much enlarged, as in *Iris* (fig. 260); and in other cases they are *capitate* (fig. 256), *lobed* (fig. 261), *peltate, radiate* (fig. 262), *filiform* (fig. 263), *linear* (fig. 264), &c. In Leguminosæ the stigmatic surface of the simple style is *lateral* (fig. 265).

The orifice of stigmas leading to the canal of the style is more or less filled by the glandular and capillary processes which clothe their surfaces; and, indeed, to the naked eye, the canal of the style does not appear permeable.

231. The *pistils* of Gymnospermous plants consist of scales or *open carpels*, collected into *cones*, bearing exposed ovules, so that no representative of the stylar or stigmatic regions exists here. Among the Coniferæ, *Pinus* and its allies have scale-like carpels with a pair of ovules on the upper surface, at the base (fig. 266); the structure is analogous, although the form of the scale differs, in *Thuja*; the Cypress has peltate scales, with numerous ovules; in *Juniperus* each of the three scales has only one (fig. 267). In *Taxus* the ovule is a solitary structure, a kind of free ovule, growing out from the apex of a small cone formed of barren scales. In the Cycadaceæ, *Cycas* has large leaf-like carpels, with numerous marginal ovules; *Zamia* has peltate scales, more like *Cupressus*, with the ovules pendent from the thickened summit.

Fig. 263.

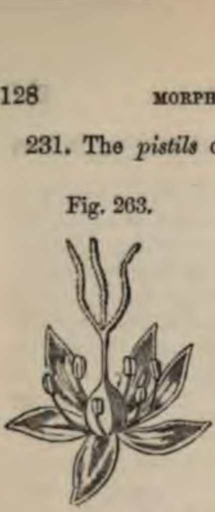


Fig. 264.

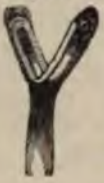


Fig. 265.

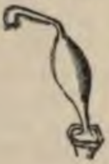


Fig. 266.

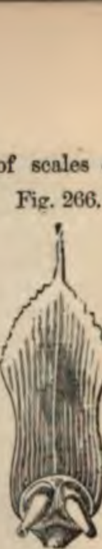
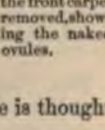


Fig. 263. Flower of *Luzula*, with filiform stigmas.
Fig. 264. Linear stigmas of Composite plant, with papillose surfaces.
Fig. 265. Ovary of *Colutea*, with *lateral* stigma.
Fig. 266. Open carpel of *Pinus*, with two naked ovules.

Fig. 267.



Young female blossom of *Juniperus*, with the front carpel removed, showing the naked ovules.

By some authors what is above described as a naked ovule is thought to be an ovary.

## Sect. 10. PRODUCTS OF THE ESSENTIAL ORGANS OF FLOWERS.

### *The Ovule.*

232. Ovules are the rudiments of seeds, and arise from the placentas, situated in the ovaries of Angiospermous plants (figs. 253–255), and on the margins or surface of the open carpels of Gymnospermia (figs. 266, 267). They originate as cellular papillæ at an early stage of development of the ovary, and acquire a definite form and structure by the time the flower expands.

Ovules are usually regarded as a kind of bud; not only do they appear in the positions occupied by adventitious buds on vegetative leaves, as in *Bryophyllum* (§ 109), but abnormal leaf-like carpels often bear bulb-like structures and foliaceous lobes, in place of the ovules, on their free ortive-placental margins.

233. The number of ovules in an ovary, or in one cell of a compound ovary, varies between wide limits. Thus the ovule is *solitary* in the simple ovaries of *Ranunculus, Rosa, Prunus* (fig. 245), &c., in the compound ovaries of Polygonaceæ &c., and in each cell of the bilocular ovaries of the Umbelliferæ &c.; the number is still small and *definite* in the simple pistils of many Leguminosæ, in the cells of the compound ovary of *Quercus* &c.; in a very large proportion of compound ovaries, whether unilocular or multilocular, the ovules are very numerous on each placental surface, and they are termed *indefinite*, as in *Primula, Papaver, Digitalis*, &c. &c.

234. A fully developed ovule is usually attached to the placenta by a short stalk, called the *funiculus, podosperm,* or *umbilical cord*; where this stalk does not exist, the ovule is *sessile*; in a few cases the funiculus is very much elongated (Plumbaginaceæ).

235. Special terms are used to indicate the position occupied by ovules in the ovary, and more particularly their direction. If the placenta is at the base of the ovary, and the ovule, springing from that situation, points upward, as in Polygonaceæ and Compositæ, it is called *erect*; if it is attached at the summit, and hangs straight down, as in the Birch, Dipsaceæ, &c., it is *suspended*; when the placenta is central or parietal, the ovule may turn upwards and be *ascending*, may point straight outwards or inwards, and be *horizontal*, or may turn downwards, and be *pendulous*. In Plumbaginaceæ the ovule is suspended from the end of a long funiculus which arises from the base of the ovary as in the erect condition.

Where numerous ovules exist on a central placenta, it is very common to find the upper ones ascending, the middle horizontal, and the lower pendulous, so that the direction becomes indefinite.

236. The ovule arises from the placenta as a conical papilla, which soon becomes elongated into an oval body, the *nucleus*, raised on the stalk or *funiculus*. By the time the flower opens, the *nucleus* (figs. 268–270, *a*) generally becomes covered up by the *coats* or envelopes, which originate as circular ridges from the point where the funiculus is attached, and gradually grow up over the nucleus. The coats do not completely close in the ovule, but leave an opening at its summit, called the *micropyle*, or *foramen* (figs. 268–270, *b*). The base of the nucleus, where the coats arise, is called the *chalaza*; the internal coat (the *secundine* of Mirbel) is the first formed; it is denominated the *integumentum internum*, or the *tegmen*; where only one coat exists, it is called the *integumentum simplex*. The outer

coat, which grows up after the inner (the *primine* of Mirbel), is called the *integumentum externum*, or sometimes the *testa*. Sometimes, as in *Welwitschia*, the primine is prolonged beyond the apex of the ovule in the form of a tube greatly resembling a style. The orifice named the *micropyle* forms a canal passing through both coats down to the point of the nucleus; and the portions passing through the outer and inner integuments are often called, respectively, the *exostome* and *endostome*. The point where the seed afterwards breaks away from the funiculus is marked by a scar, which is called the *hilum*.

Fig. 268.

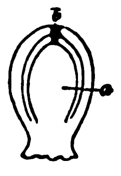


Fig. 269.

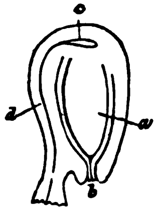
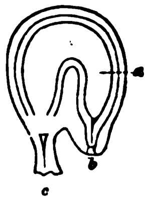


Fig. 270.



Diagrammatic vertical sections of ovules: *a*, the nucleus; *b*, the micropyle; *c*, chalaza; *d*, raphe.

Fig. 268. An atropous or orthotropous ovule.
Fig. 269. An anatropous ovule. Fig. 270. A campylotropous ovule.

In the Mistletoe the nucleus is naked, no coats being formed; in many cases there is only one coat; most ovules of Monocotyledons have two.

The coats of the ovule are usually regarded as foliar in their nature, the nucleus as axial.

237. The above is a description of the ovule of what may be called the normal form, such as we find in *Polygonum*, &c.: where the nucleus is straight and the *micropyle* is at the end opposite the attachment of the *funiculus*, and the *chalaza* next the *placenta*, such an ovule is called *straight*, or more technically *atropous* or *orthotropous* (fig. 268).

238. Very frequently the *funiculus* grows, in a state of confluence with the outer integument, during the development of the ovule, so as to push up the base of the nucleus until it is completely inverted (fig. 269), and the micropyle (*b*) points to the placenta, while the chalaza (*c*) is at the opposite end; this is the *inverted* or *anatropous* condition (Compositæ, Papaveraceæ, Liliaceæ, Orchidaceæ, &c. &c.); and as the funiculus is confluent with the outer coat, the *hilum* (the external point of junction of the *funiculus* with the body of the ovule) is left in its original position, and therefore close beside the inverted micropyle: the adherent portion of the funiculus often forms a kind of ridge extending from the hilum to the chalaza; this is termed the *raphe* (fig. 269, *d*).

The inverted ovule is only a straight ovule with a long funiculus coherent with the outer coat: in *Fumana* (Cistaceæ) the real condition then actually illustrates this; and in seeds formed from anatropous ovules the raphe sometimes separates (*Zygophyllum*). The position of the raphe with reference to the ovule varies in different cases; sometimes it is *ventral* or on the side of the ovule nearest to the placenta, sometimes dorsal, at other times lateral.

239. A curved or *campylotropous* ovule (fig. 270) is formed by the folding over of the nucleus upon itself in the form of the letter U, carrying the *micropyle* (*b*) over, but leaving the *chalaza* in its natural vicinity to the hilum. Externally this ovule resembles the anatropous, except that there is *no raphe* (Cruciferæ, Caryophyllaceæ, &c.).

240. Another condition more rarely met with is the horizontal or *amphitropous* ovule, intermediate between straight and inverted, the adherent funiculus pushing up the chalaza at one end, while the micropyle descends in a corresponding degree, until the axis of the ovule becomes horizontal, and parallel with instead of at right angles to the placenta.

In the first instance all ovules are straight, but mostly become curved during the course of their development.

241. At the time when the flower expands, there exists a more or less considerable sac or cavity excavated in the substance of the nucleus, the upper end of which sac is situated just within the apex. This cavity is called the *embryo-sac*, being really a sac or bag with a proper wall, within which the *embryo* or rudiment of the future plant is developed after fecundation.

The phenomena of fecundation and of the early development of the embryo, together with the minutiæ of the anatomy of ovules, are reserved for the Physiological part of this work.

The further morphological peculiarities of the ovular structures will fall best under the head of the *seed* or completed product, previously to examining which we must follow out the ultimate history of the pistils and associated organs forming the *fruit*, in which the ripe seeds are found.

## *The Fruit.*

242. The fertilization of the ovules usually takes place soon after the opening of the flowers, or sometimes even before their expansion. During the subsequent changes by which the ovules are converted into seeds, the ovary (and occasionally other parts of the flower) undergoes further development, and becomes what is technically called the *fruit*.

Generally the stamens and corolla, and not uncommonly the calyx also, fall away or wither up after fertilization, and the styles, with the stigmas, mostly disappear; but the style sometimes persists, and even undergoes enlargement, forming a kind of *beak* or *tail* to the fruit, especially in simple fruits formed of one carpel (*Ranunculus*, *Clematis*, *Geum*, fig. 285), &c.

The calyx, when *inferior*, remains in many cases as a loose cup or envelope surrounding the fruit (as in Labiatæ, many Solanaceæ, fig. 291, &c.); or, when *superior*, its segments, enlarged or withered, form a kind of crown to the fruit (Compositæ, Campanulaceæ, &c.), and the tubes of adherent calyces always enter into the composition of the inferior fruits (figs. 296–303). In some cases the calyx and the corolla, in other cases the receptacle, become blended with the ovary or ovaries to form the fruit; and a still more complex kind of fruit is formed by all the flowers of an inflorescence becoming conjoined into a common structure during the ripening of the seed, so as to form a collective fruit, such as occurs in the Pine-apple (fig. 307), Mulberry (fig. 306), Bread-fruit, the Fig (fig. 305), cones of Firs, &c.

Considered as developments of the carpels alone, many fruits in their mature condition depart widely in appearance from the ovaries from which they are produced, the morphology of fruits exhibiting perhaps more remarkable cases of actual metamorphosis than any other parts of plants. Hence it is often difficult to judge from a fruit what kind of pistil the flower has possessed, and the structure of fruits can only be understood by a study of their progressive development from the immature to the mature condition.

The most important source of change is the suppression of chambers or loculi of the ovary, together with the abortion of ovules. Thus the flower of the Birch has a two-celled ovary with one ovule in each cell; but one cell with its ovule is constantly abortive and almost entirely disappears in the fruit. In the female flower of the Oak there are three cells, each with two ovules (fig. 271); but only one cell is found in the ripe fruit, and this is filled by one solitary remaining seed, as we find in the Acorn. In the Lime there are several cells in the ovary, but generally all but one are obliterated in the fruit (fig. 272); and similar cases are by no means uncommon. In these cases the dissepiments, called in the fruit *septa*, are not broken down, but pushed to one side and obliterated by the pressure exercised by the developed seed.

On the other hand *spurious* partitions are sometimes formed, as in *Datura Stramonium*, which has a four-celled fruit derived from a two-celled ovary; and in the pods of Leguminosæ cross partitions are often produced between the seeds.

The original conditions are frequently still further disfigured by the alterations in the texture of the coverings of the fruit, next to be described.

Fig. 271.

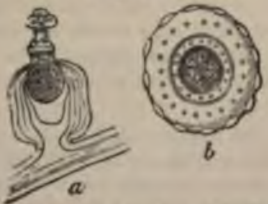


Fig. 272.

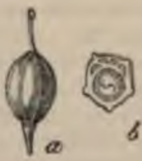


Fig. 271. Female flower of the Oak: *a*, vertical section; *b*, cross section.
Fig. 272. Fruit of the Lime (*Tilia*): *a*, entire; *b*, cross section.

243. The "wall" of the fruit is the substance formed from the carpels, or (when present) from the other component structures (§ 242). It constitutes the case enclosing the ripe seed or seeds, and is called the *pericarp*. The *pericarp* is of very different structure in different fruits. When the fruit is mature, it may be *dry*, *membranous*, *leathery* (*coriaceous*), or *woody*; or *succulent*; or succulent externally and woody within, or, *vice versâ*, succulent internally and woody or leathery outside.

The pods of common Peas, the capsules of Pinks, Poppies, &c., afford examples of a dry membranous pericarp; the Flags have a *leathery* pericarp; the common Hazel-nut, Acorn, capsules of the Mahogany-tree, &c. have a *woody* pericarp. The pericarps of the Grape and the Gooseberry are *succulent*. The Plum, Cherry, &c. are succulent externally and woody within; the Orange, the Pomegranate, the Pumpkin, &c. are succulent within and leathery or horny outside.

244. When the *pericarp* is uniformly membranous or woody, without distinction of layers, no subdivisional terms are applied to it. The same holds good in respect to the simple *succulent pericarp* of such fruits as the Grape and Gooseberry. When there is a distinction into layers, formed by a gradual alteration of the texture of the inner and outer parts during maturation, we distinguish between an *epicarp* and an *endocarp*, as, for example, in the Plum, Cherry, Walnut, &c., where there is a succulent *epicarp*, and a woody *endocarp* forming the "stone;" the "core" of the Apple is a membranous endocarp. When a fruit, such as the Orange, Pomegranate, Litchi, &c., is firm externally, with a leathery or woody *epicarp*, and a succulent *endocarp*, the latter is generally derived from development from the placental regions. In common "stone-fruits" the two regions are often distinguished by the names *sarcocarp* (or pulp) and *putamen*. In the Date (fig. 280) the "stone" consists of the albuminous seed, which is invested by a succulent pericarp. In other Palms, such as *Areca*, the pericarp is fibrous. In hard-rinded succulent fruits we have an internal *sarcocarp* enclosed by a *cortex* or rind.

Many authors, following DeCandolle, divide the pericarp into *epicarp*, *mesocarp*, and *endocarp*. It may be observed here that the distinction between endocarp and epicarp, in the common stone-fruits, arises entirely during the ripening of the fruit; the two regions are originally alike and undistinguishable; it is well known that the easy separation of the pulp from the stone is a sign of ripeness.

245. Some fruits, more particularly the succulent kinds, but also many dry fruits, do not burst to discharge their seed or seeds when ripe; these are called *indehiscent fruits*. The pericarp rots away, or is broken irregularly or perforated when the seed germinates. Most dry fruits, more particularly those formed of more than one carpel, burst open or separate into pieces in a regular manner when mature, and are consequently *dehiscent*.

246. *Dehiscence* takes place generally by the separation or splitting of the sutures of the carpels in a vertical direction, or by the disunion of coherent carpels, or by both together. The parts which separate in this way are called *valves*; and this mode of bursting is termed *sutural* or *valvular dehiscence.* Sometimes the valves only separate for a certain distance from the summit, forming little segments or teeth (fig. 273). In a few cases the dehiscence is *porous*, or by pores or orifices formed in the walls; in others the upper end of the fruit falls off like a lid, by *transverse* or *circumscissile dehiscence* (fig. 274).

Fig. 273.

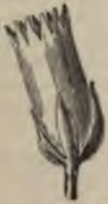


Fig. 274.

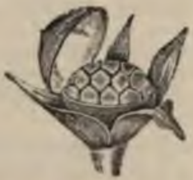


Fig. 275.

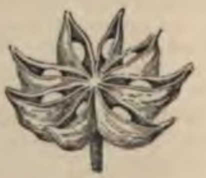


Fig. 273. Burst capsule of *Cerastium*.
Fig. 274. Capsule of *Anagallis*, opening by circumscissile dehiscence.
Fig. 275. Burst fruit of *Illicium* (Star Anise).

247. When the dehiscence is *valvular* the fruit is named bi-, tri-, multivalvular according to the number of valves or pieces into which it splits. This mode of dehiscence is subject to several modifications, according as the splitting takes place through the dorsal or through the ventral suture, or through both at the same time. It is still further complicated by the circumstance that the placentas sometimes remain attached to the valves, while at other times they break away from the valves, as in the condition called *septifragal.*

A few examples may be here given of the various modes in which valvular dehiscence is effected; and the student will find the subject far more readily intelligible if he refer to some collection of seed-vessels where the fruits are correctly named. In the case of *simple* or of *apocarpous* fruits, valvular dehiscence takes place:—*a*, through the ventral suture, as in the Columbine (*Aquilegia*), the Star Anise (*Illicium*, fig. 275); or, *β*, through the dorsal suture, as in *Magnolia*; or, *γ*, through both sutures at the same time, as in the pod of the pea and other Leguminous plants (fig. 282). In this latter case there are two valves, but only a single carpel.

In one-celled *syncarpous* fruits, where the component carpels cohere by their edges which are not infolded, dehiscence takes place:—*a*, through the ventral sutures, when the placentas are found on the margins of the valves, as in Gentians, each valve in this case representing a carpel; *β*, through the dorsal sutures, when the placentas will be found in the middle of the valves, as in the Violet (*Viola*). In such fruits each valve consists of two half-carpels combined together. In the Orchidaceæ the capsules dehisce in the manner last described, with this further peculiarity—that the valves, bearing the placentas in the middle, separate from the midribs or dorsal sutures, leaving these latter attached together at the top, and thus forming an open framework supporting the remains of the perianth.

In *many-celled syncarpous* fruits, where the sides and margins of the component carpels are infolded, dehiscence taken place :—*a*, *loculicidally*, through the dorsal suture, so as to open the loculus or cavity of the carpel from behind ; each valve in this case represents two half carpels (figs. 277, 278) ; or, *β*, *septicidally*, through the septa, so as to isolate the previously combined carpels (fig. 276). Each valve in this case represents an entire carpel. In some instances, as in *Umbelliferæ*, Bedstraw, *Galium*, &c., the carpels merely separate in this manner, one from the other, without opening. In such a case the term *schizocarp* is employed to designate the whole fruit, while its constituent carpels are called *cocci*, or sometimes *mericarps*. More frequently the carpels not only separate septicidally from their fellows, but each one bursts, either through the dorsal suture, as in *Geranium* (fig. 276), *Euphorbia*, or through the ventral suture, as in *Colchicum*.

Fig. 276.

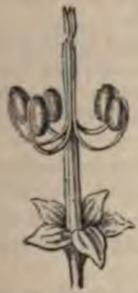


Fig. 277.

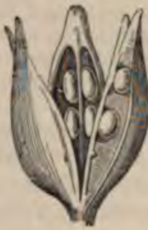


Fig. 278.

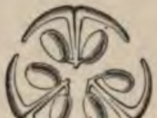


Fig. 276. Ripe fruit of *Geranium*, the tailed *cocci* separating elastically from the carpophore.
Fig. 277. Burst capsule of *Iris*, with loculicidal dehiscence and septicidal separation of the placentas at the sutures.
Fig. 278. The same in cross section.

Thus septicidal and loculicidal dehiscence may occur in the same fruit, as in the Foxglove (*Digitalis*), the capsule of which first divides into its constituent carpels septicidally, and afterwards each carpel splits loculicidally into two valves ; the four valves so produced represent each a half-carpel.

Both the loculicidal and septicidal modes of dehiscence are sometimes associated with what is termed *septifragal* dehiscence. This occurs when the *septa* or partitions bearing the placentas are broken across ; the effect of this is that the valves break away from the placentas, leaving part or the whole of the latter standing in the centre of the fruit on a kind of column, as in *Andromeda*, *Convolvulus*, *Rhododendron*, &c. *Septifragal dehiscence* takes place by itself in the *siliques* or pods of Cruciferæ, where the valves separate from the parietal placentas, leaving them in the centre supporting the ovules (figs. 292 & 293).

248. *Dehiscence by teeth* only differs from that by valves in the smaller

degree of separation. The fruits or seed-vessels of Caryophyllaceæ dehisce by teeth. Sometimes the teeth are equal in number to the carpels, as when the dehiscence is through the ventral sutures only (*Lychnis*); sometimes double the number of the carpels, when the splitting takes place through both sutures (*Dianthus*).

249. *Porous* dehiscence arises from the formation of orifices in the walls of a dry capsule, allowing the seeds to escape. In the Poppy (*Papaver*) a circle of *pores* is formed round the upper edge of the fruit, just beneath the stigma; in *Antirrhinum* and *Linaria* there are two or three orifices near the summit of the capsule; in some Campanulas a pore is formed at the base of each cell.

In all these cases the orifices are formed from thin spots in the walls, which tear open, their edges curling back in more or less regular teeth: the dehiscence of *Antirrhinum* is connected by that of *Scrophularia*, *Digitalis*, &c., with the dehiscence into a crown of teeth as in *Primula* and Caryophyllaceæ.

250. *Transverse*, or *circumscissile dehiscence*, observed in the membranous capsules of *Hyoscyamus* (fig. 291), *Anagallis* (fig. 274), *Plantago*, &c., and in the woody fruits of *Lecythis*, arises from a transverse fissure running round the wall and splitting off the upper part of the fruit like a lid.

A dehiscence analogous to this occurs in the *lomenta* of various Leguminosæ, which break across between the seeds.

In these cases a kind of articulation is produced, by the tissue of the pericarp remaining more delicate in the line of dehiscence, so that it becomes torn by the hygrometric contraction or expansion of the firmer parts above and below, after the fruit has become mature.

251. The apex of dry fruits is marked by the position of the style itself when persistent (fig. 285 *b*), or by a scar indicating the place of separation. The axis of a compound fruit is commonly an imaginary line; but in Umbelliferæ (fig. 301) and Geraniaceæ (fig. 276) the *carpophore* forms a true axis, from which the carpels separate in dehiscence.

252. Dehiscence does not usually take place until the seeds are ripe; but in Mignonette the upper end of the ovary opens long before; in *Leontice thalictroides* the ovary bursts very early, and the seed ripens in a naked condition. In *Impatiens* and some other plants dehiscence takes place suddenly with considerable force, the valves separating and rapidly curling up. In *Elaterium* the peduncle separates in a similar sudden way from the ripe fruit, and the seeds are forcibly ejected.

253. In Gymnosperms there is of course no proper dehiscence; but in most cases the carpellary scales of the female cones, which are separate to some extent during fertilization, frequently close up together so as to form an apparently solid body while the seeds are

ripening, as in *Pinus*, *Cupressus*, *Thuja*, &c. The scales open again when the seeds are ripe, and in some cases separate from the axis. In *Juniperus* the scales become succulent, so as to form a berry-like organ. In *Taxus* the solitary ovule is always naked; and during the ripening of the seed a succulent cup-like envelope grows up round it.

254. The forms of perfect fruit are distinguished by technical names, and in defining them it is desirable to classify them in some way. The classification which conveys the greatest amount of information is that founded primarily on the construction of fruits.

The multitude of names which have been invented, the vague manner in which many of these have been used, added to the not unfrequent polymorphism of fruits within the limits of single Natural Orders, render a satisfactory classification of fruits almost impossible without naming them all afresh, and defining them according to their mode of development as well as their perfect condition; and this, after all, would necessitate a terminology too cumbrous for use in Descriptive Botany, for which the names and definitions are chiefly required.

255. Fruits may be divided first into *free* or *monothalamic fruits*, formed from single flowers, and *confluent fruits*, formed of the blended flowers of an inflorescence. The term *polythalamic* has been conveniently applied to fruits of this latter kind.

*Free fruits* may be divided into :—1. *Apocarpous fruits*, where the constituent carpels are separate, forming (*a*) *simple fruits* when the carpel is solitary, (*b*) *multiple fruits* when more than one is found on the same receptacle; 2. *Syncarpous fruits*, formed of compound ovaries, and consisting of (*a*) *superior fruits* when the calyx is free, and (*b*) *inferior fruits* when the tube of the receptacle or of the calyx is adherent.

*Confluent fruits* require no corresponding subdivision.

Almost all of the above groups are again divisible into *dry* and *succulent* kinds; this diversity is so special, occurring between nearly allied genera in the same Natural Orders, that it seems unadvisable to make it a basis for any of the main sections. Modes of dehiscence and absence of dehiscence characterize subordinate kinds of dry fruits.

256. The following classification is a slightly modified form of that established by Dr. Lindley. In it all or nearly all the forms described by various authors are enumerated, but comparatively few are in general use. Some of these will be found more fully described in subsequent paragraphs:—

## CLASSIFICATION OF FRUITS.

### A. *Free or Monothalamic Fruits.*

I. APOCARPOUS, composed of distinct simple carpels.

- * Simple monocarpous fruits (formed from solitary carpels).
  - † Pericarp formed from the ovary alone.
    - ‡ Pericarp uniform.
      - ‖ One- or few-seeded.
        - Pericarp horny and indehiscent . *Achænium.*
        - Pericarp membranous, sometimes dehiscent . . . . . . . . *Utriculus.*
      - ‖‖ Many-seeded.
        - Dehiscent by the ventral suture . *Folliculus.*
        - Dehiscent by both sutures . . . *Legumen.*
        - Indehiscent or articulated transversely . . . . . . . . . *Lomentum.*
    - ‡‡ Pericarp of two or more layers.
      - Epicarp fleshy, endocarp bony . *Drupa.*
  - †† Pericarp formed from the ovary and adherent floral envelopes.
    - Dry, indehiscent . . . . . . . *Diclesium.*
    - Fleshy . . . . . . . . . . *Sphalerocarpium.*
- ** Multiple or polycarpous fruits, formed of an assemblage of distinct carpels.
  - † Free.
    - Pericarps distinct, dry (*achænia*) or fleshy (*drupes*) . . . . . . . *Etærio.*
    - Pericarps ultimately more or less coherent . . . . . . . . . . . *Syncarpium.*
  - †† Enclosed in a cup-like fleshy receptacle. *Cynarrhodum.*

II. SYNCARPOUS, composed of combined carpels.

- * Superior.
  - † Pericarp dry.
    - ‡ Indehiscent.
      - One-celled, one-seeded, pericarp adherent to the seed . . . . *Caryopsis.*
      - One- or many-celled, winged, pericarp not adherent to the seed or seeds . . . . . . . . . *Samara.*

- ‡‡ Dehiscent.
  - ⊕ Separating into indehiscent cocci . *Carcerulus.*
  - ⊕⊕ Separating into dehiscent cocci . *Regma.*
  - ⊕⊕⊕ Separating into two pseudo-follicles . . . . . . . . . *Conceptaculum.*
  - ⊕⊕⊕⊕ Dehiscence transverse . . . *Pyxis.*
  - ⊕⊕⊕⊕⊕ Dehiscence valvular or porous.
    - ◎ Placentas parietal in a two-celled ovary.
      - Linear . . . . . . . . . *Siliqua.*
      - Short and broad . . . . . *Silicula.*
    - ◎◎ Placentas axile in two- or many-celled ovaries, free central or parietal in 1-celled ovaries . . . . . . . . *Capsula.*
- †† Pericarp fleshy, indehiscent.
  - ‡ Pericarp uniform . . . . . . . . *Nuculanium.*
  - ‡‡ Pericarp of two or more layers.
    - Epicarp coriaceous or woody, endocarp fleshy . . . . . . . . *Amphisarca.*
    - Epicarp fleshy, forming a spongy rind; endocarp pulpy. . . . *Hesperidium.*

** Inferior.

- † Pericarp dry.
  - ‡ One-celled by suppression, indehiscent, within a cupulate involucre . . . *Glans.*
  - ‡‡ Genuinely one-celled and one-seeded, often with a pappus . . . . . *Cypsela.*
  - ‡‡‡ Two- or many-celled.
    - Separating into indehiscent cocci. *Cremocarpium.*
    - Dehiscing by valves or pores . . *Diplotegia.*
- †† Pericarp fleshy, at least within.
  - ‡ Pericarp simple, seeds more or less free in the pulp . . . . . . . . . *Bacca.*
  - ‡‡ Pericarp of two or more layers.
    - ⊕ Epicarp fleshy, endocarp parchment-like or bony, indehiscent . . *Pomum.*
    - ⊕⊕ Epicarp fleshy or fibrous, endocarp bony, dehiscent . . . . . *Tryma.*
    - ⊕⊕⊕ Epicarp horny or crustaceous, endocarp fleshy.
      - One-celled, seeds on pulpy parietal placentas. . . . . . . . . *Pepo.*
      - Many-celled, seeds with a pulpy coat . . . . . . . . . *Balausta.*

### B. *Polythalamic or Confluent Fruits.*

| | |
|---|---|
| I. ANGIOSPERMOUS, formed of closed ovaries. | |
| Pericarps of the constituent flowers hard, imbedded in the fleshy axis of the inflorescence. | *Syconus.* |
| Pericarps of the constituent flowers succulent and confluent with each other and sometimes with the axis of inflorescence . . . | *Sorosis.* |
| II. GYMNOSPERMOUS, formed of open carpels. | |
| Constituent carpels scale-like, imbricated in a conical group . . . . . . . . . . . . | *Strobilus.* |
| Constituent carpels peltate and forming a globular head . . . . . . . . . . . . | *Galbulus.* |

The above classification is far from satisfactory: for students' purposes it is too complicated; and, moreover, in practice the majority of descriptive botanists, finding it next to impossible accurately to classify all the varieties of fruit they meet with, content themselves with the employment of a few well-understood terms applied more generally than is the case in the foregoing scheme. In the following paragraphs those terms which are in most frequent use are printed in larger type, those not in general use are in smaller type. The student with a ripe fruit before him is mainly concerned with the fruit in its existing condition; an arrangement founded on the peculiarities of the transitional stages between the immature pistil and the ripe fruit is necessarily embarrassing to him, since, as a rule, he has only limited means of ascertaining for himself the course of development. This, however, may to a great extent be understood from a mere comparison of the pistil with the ripe fruit.

### *Simple Fruits.*

257. The *Achænium* is a small, dry, indehiscent, one-seeded pericarp, tipped with the remains of the style, and with the seed free in the interior, except at the point of attachment.

This fruit is rarely found solitary, as in *Alchemilla*; it usually forms

Fig. 279.

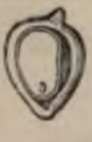


Fig. 280.

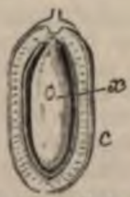


Fig. 281.

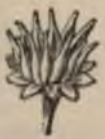


Fig. 279. Achænium of *Ranunculus* cut vertically to show the seed.
Fig. 280. Section of the drupe of the Date (*Phœnix dactylifera*): *c*, the pericarp; *x*, the embryo imbedded in the horny albumen.
Fig. 281. Circle of follicles of *Sempervivum*.

part of a multiple fruit, as in *Ranunculus*, *Clematis*, *Geum* (fig. 285), &c. Achænia are popularly mistaken for seeds, from which they may be known by the stylar beak, and by the seed lying looseinside.

The term achænium is often applied to the halves of Umbelliferous fruits, the cocci of Mallows, the *nucules* or *nuts* of Labiatæ, &c. (the carcerule of some authors) (fig. 290), and to the "cypselæ" of Compositæ.

258. The *Utriculus.*—This differs from the achænium chiefly in the membranous character of the pericarp, and in dehiscing sometimes by a transverse slit; it is found in *Chenopodium*, *Amaranthus*, &c.

259. The *Diclesium* only differs from the utriculus in having the indurated perianth adherent to the carpel, and forming part of the shell (*Mirabilis*, *Salsola*).

260. The *Sphalerocarpium* resembles the preceding in structure; but the complex pericarp is fleshy, forming a berry-like body (*Hippophaë*, *Blitum*). For practical purposes this is best classed as a berry.

261. The *Drupe* is a one-celled fleshy fruit, represented by stone-fruits formed from a single pistil, such as the Cherry, where the stone is formed by the inner part of the pericarp, and the pulp by the outer part.

In common stone-fruits the drupe is solitary; but minute drupes formed on the same plan are assembled together on the receptacle in the etærio of the Raspberry and Blackberry (fig. 286). The term drupe is often improperly applied to the compound stone-fruits, like the Cocoa-nut &c.,—or to the Date, where the stone is formed by the seed alone, and the pulp by the pericarp (fig. 280).

262. The *Follicle* is a simple pod, splitting down the ventral suture, and bearing the numerous ovules on its margins.

This rarely occurs solitary, but mostly combined with others in a circle, as in *Aquilegia*, *Pæonia*, *Sempervivum* (fig. 281), &c.; and they are then often coherent at the base, so as to form a transition to the *syncarpium*. The pair of follicles (*conceptacula*) of Asclepiadaceæ have their placentas detached when they dehisce, so as to set the seeds free.

263. The *Legume* is a one- or many-seeded simple fruit, usually splitting into two valves, with the placentas on the margins of the ventral suture.

In most cases the *legume* is elongated and pod-like (fig. 282), as in the Pea &c.; but sometimes it is curved or even spirally coiled like a snail's shell, as in *Medicago* (fig. 283), or lobed and knotted, as in *Acacia* (fig. 284). In *Astragalus* a spurious sutural septum is formed by projection inward of one of the sutures (fig. 252).

264. The *Lomentum* is a modification of the legume, either wholly indehiscent, or constricted into joints between the seeds and sometimes falling to pieces in these situations, as in *Ornithopus*, *Desmodium*, &c. In the lomentum of *Cassia* (e. g. *Cassia fistula*) there are many false cross septa.

### *Multiple Fruits.*

265. The *Etærio* is formed either of an assemblage of *achænia* on a *dry* receptacle (*Ranunculus*, *Geum*, fig. 285), or on an enlarged *pulpy* receptacle, Strawberry (*Fragaria*), or of a collection of small *drupes* on a dry or spongy receptacle, Blackberry (*Rubus*, fig. 286).

Fig. 282.

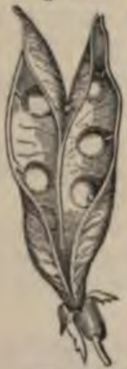


Fig. 283.

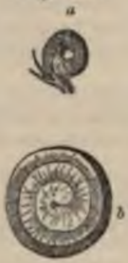


Fig. 284.

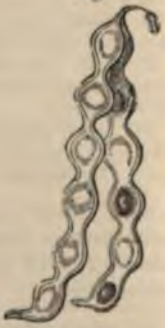


Fig. 282. Legume of Pea, burst.
Fig. 283. *a*, Curled legume of *Medicago sativa*; *b*, of *Medicago orbicularis*.
Fig. 284. Legume of an *Acacia*.

Fig. 285.

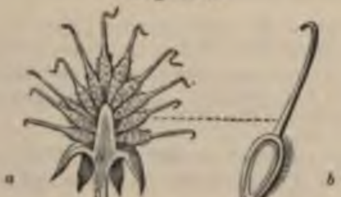


Fig. 286.

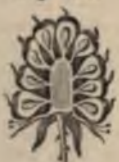


Fig. 285. Dry etærio of *Geum*, cut vertically (*a*) to show the attachment of the component achænia (*b*).
Fig. 286. Pulpy etærio of Blackberry (*Rubus*) cut vertically, showing the spongy receptacle covered with little drupes.

The circle of follicles in *Aquilegia*, *Delphinium*, &c. nearly approaches this, as do also the fruits of Wintereæ (*Illicium*, fig. 275).

266. The *Syncarpium* is formed by the confluence into a solid mass of the carpels of a multiple ovary with a slender receptacle (*Anona*, *Magnolia*).

267. The *Cynarrhodum* consists of a succulent outer envelope, formed of a cup-like receptacle (according to some, of the tube of the calyx), with numerous achænia lining the walls (*Rosa*, *Calycanthus*).

### *Compound Fruits—Superior.*

268. The *Caryopsis* is the one-seeded fruit of the Grasses, composed of two, or rarely three carpels, which form a dry pericarp inseparable from the seed. In practice it is hardly recognizable from the achene, except in the last-mentioned characteristic.

269. The *Samara* is a two- or more-celled, few-seeded, dry, indehiscent fruit, which has a membranous wing or wings developed from the pericarp—as in *Acer* (fig. 287), *Ulmus* (fig. 288), and the little fruits of the catkin of the Birch (fig. 289). Practically this may be regarded as one or more achenes with winged pericarps.

Fig. 287.

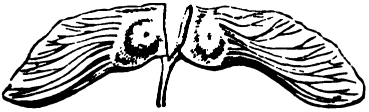


Fig. 288.

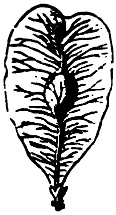


Fig. 287. Double samara of the Maple (*Acer*). Fig. 288. Samara of the Elm (*Ulmus campestris*).

270. The *Carcerulus* is a dry fruit formed from a many-celled ovary, the carpels of which separate when ripe into indehiscent few-seeded *cocci*. The term *schizocarp* is sometimes applied to such a fruit.

This fruit occurs in various modifications, in *Malva*, *Tropæolum*, Boraginaceæ (fig. 290), Labiatæ, &c.; the cocci are sometimes called *nucules*, and are often regarded as achenes.

Fig. 289.

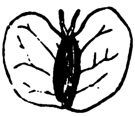


Fig. 290.

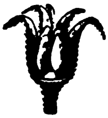


Fig. 289. Samaroid fruit of the Birch (*Betula alba*).

Fig. 290. Persistent calyx of a Boraginaceous plant, opened to show the carcerulus formed of four indehiscent carpels, separating from each other.

271. The *Regma* differs from the foregoing chiefly in the cocci being individually dehiscent, as in *Euphorbia*, *Geranium*, &c.

In *Geranium* the cocci remain attached for a time by the persistent beak-like segments of the style to the summit of a carpophore, the beaks often coiling spirally (fig. 276).

272. The *Conceptaculum* is formed by a two-celled, many-seeded ovary, separating into two dry follicular valves, in which the seeds lie loose. It may be described as a pair of follicles. Examples may be met with in Asclepiads.

273. The *Pyxis* is a one- or more-celled, many-seeded fruit, the upper part of which falls off like a lid by circumscissile dehiscence, as in *Anagallis* (fig. 274), *Hyoscyamus* (fig. 291), *Lecythis*, &c. It differs from the capsule merely in its transverse dehiscence.

274. The *Siliqua.*—This is a two-valved linear pod, the valves of which separate septifragally from a kind of frame, with a more or less perfect false septum (*replum*) stretched across it, the (*parietal*) placentas being attached to the frame, as in *Sinapis* (fig. 292), *Cheiranthus, Matthiola*, &c.

Fig. 291.

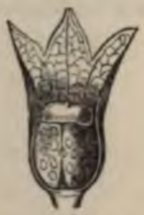


Fig. 293.

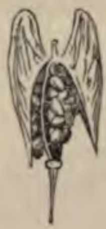


Fig. 292.

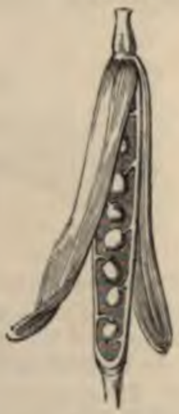


Fig. 294.

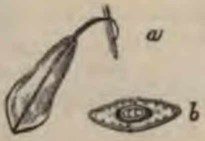


Fig. 291. Pyxis of *Hyoscyamus*, enclosed in the dry calyx.
Fig. 292. Burst siliqua of *Sinapis*, the valves separating from the sutures supporting the replum.
Fig. 293. Burst silicle of *Thlaspi*.
Fig. 294. Indehiscent fruit of *Isatis*: *a*, entire; *b*, a cross section.

275. The *Silicula* (diminutive of the last) is merely a short and broad siliqua, often most expanded in the direction at right angles to the *replum*, the valves sometimes winged—*Thlaspi* (fig. 293), *Capsella*, &c.

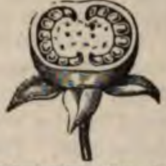
When the *replum* is imperfect, it is said to be *fenestrate* if slit; or it may be destroyed altogether. Some siliquas and siliculas do not burst by valves—*Crambe, Raphanus, Isatis* (fig. 294), &c.

276. The *Capsula* includes all the remaining kinds of dry fruits, membranous or woody, formed of one-celled or many-celled compound ovaries, which dehisce more or less completely by regular valves, equal in number to or double the carpels (*Iris, Colchicum*, Caryophyllaceæ, *Digitalis, Primula*, &c.), or by pores (*Antirrhinum, Papaver*). Its mode of dehiscence may be septicidal, loculicidal, or septifragal. (See § 247.)

277. The *Nuculanium*, or *Uva*, is a superior pulpy fruit, the flesh of which contains several seeds, and is enclosed—merely by a membrane as in the Grape, where the seeds are loose in the pulp, and *Solanum* (fig. 295),

*Atropa*, &c., where the axile placentas persist, and there are two more or less distinct cells within the pulp. This is usually regarded as a "berry" (*bacca*).

Fig. 295.



Nuculanium, Uva, or superior berry of *Solanum*, cut across.

278. The *Amphisarca* is a compound many-celled superior fruit, with a woody or indurated shell enclosing an internal pulp (*Adansonia*, *Crescentia*).

279. The *Hesperidium* is a many-celled superior indehiscent fruit, with a spongy or leathery rind, and an internal pulp formed from the tissue lining the loculi, as in the Orange. This is generally described as a form of berry.

## *Compound Fruits—Inferior.*

280. The *Tryma* resembles a drupe, but is inferior; it has a fleshy or fibrous epicarp and a bony endocarp, and is spuriously one-celled and one-seeded by abortion of the remaining cells and ovules. The epicarp is fleshy in the Walnut, and the bony endocarp splits into two valves.

281. The *Glans* is a hard, dry, indehiscent fruit, spuriously one-celled from suppression, usually one-seeded, seated in a persistent involucre forming a *cupule*. In the Acorn and Hazel-nut there is a single gland in each cupule or cup, while in the Beech and Chestnut there are several.

The ovary of the Oak is 3-celled, with two ovules in each cell; but two cells with their ovules, together with one ovule of the fertile cell, are suppressed, and the wall of the ovary is converted into a bony shell, completely filled by the remaining seed. The ovary of the Birch is also 3-celled, that of the Hazel 2-celled, that of the Chestnut 3–8-celled; and similar suppression takes place. The inferior character of the fruit is marked, especially in the Chestnut, by the remains of the teeth of the calyx on the summit. In the Acorn the gland is naked above, seated in a cup; in the Hazel the leafy cupule envelopes it; and in the Chestnut and Beech the spiny cupule encloses several fruits.

282. The *Cypsela* is a one-seeded indehiscent inferior fruit, developed

Fig. 296.

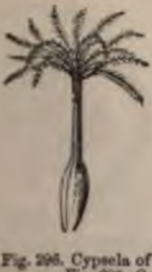


Fig. 297.

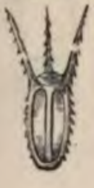


Fig. 298.

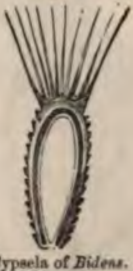


Fig. 296. Cypsela of *Scorzonera*. Fig. 297. Cypsela of *Bidens*.
Fig. 298. Cypsela sliced vertically, to show the seed within.

from a unilocular ovary, and is generally surmounted by the remains of the calyx, forming a beak, teeth, or a series of hairs or feathers (*pappus*). It is characteristic of the Compositæ (figs. 296 & 297), and, but for its pappus, is hardly distinguishable in the ripe state from the achene.

This fruit is often called an achænium.

283. The *Cremocarp* is a schizocarpous or splitting fruit, consisting of two inferior achenes formed from a two- or several-celled compound inferior ovary, the cells of which separate when ripe as indehiscent *cocci*. The separate halves of the two-celled fruit of Umbelliferæ are frequently called *mericarps* (figs. 299–301) (*Galium* and many other Rubiaceæ, &c.).

Fig. 299.

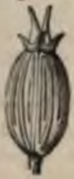


Fig. 300.

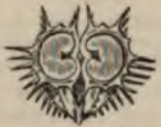


Fig. 301.

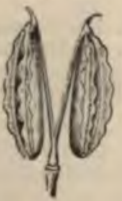


Fig. 299. Fruit of *Œnanthe*, the halves not separated.
Fig. 300. Cross section of the fruit of the Carrot.
Fig. 301. Fruit of Umbelliferæ, the mericarps separated and hanging from the carpophore.

284. The *Diplotegia* is an inferior *capsule*, one- or many-celled, dehiscing by valves or pores (*Campanula*).

285. The *Bacca*, or true berry, differs from the *nuculanium* only in being inferior, so that it is crowned by the withered teeth of the calyx; it is uniformly pulpy, with a thin skin, the numerous seeds being imbedded in the pulp (Gooseberry, Currant, Cornel (fig. 302), &c.).

Fig. 303.

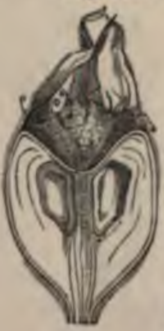


Fig. 302.

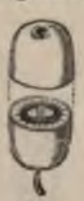


Fig. 304.

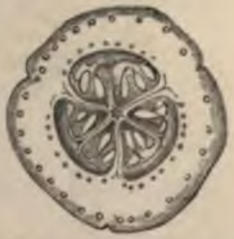


Fig. 302. Berry of Cornel (*Cornus mas*).
Fig. 303. Vertical section of the fruit of *Mespilus* (Medlar).
Fig. 304. Cross section of the pepo of Cucumber.

286. The *Pomum* is a compound, many-celled succulent fruit, in which the epicarp is fleshy, while the endocarp forms either cartilaginous linings and partitions to the cells (a "core"), or bony shells around the more or less separated cells (Apple, Quince, Medlar (fig. 303), Hawthorn, &c.). The fleshy portion of the pome consists in a dilatation of the flower-stalk, in which the true carpels are imbedded.

287. The *Pepo*, or Gourd, is a succulent inferior one-celled fruit, with the seeds on three parietal placentas, imbedded in pulp, which often fills up the cavity; the epicarp is more or less leathery (Cucumber, fig. 304), or thickened and indurated (Gourd).

288. The *Balausta* is an inferior compound fruit, with a brittle woody rind surrounding an irregular assemblage of numerous cells, in which the seeds are attached to the placentas, and have a pulpy coat (Pomegranate).

### *Infrutescences or Confluent Fruits.*

289. The *Syconus* is a succulent fruit, formed of an enlarged fleshy excavated or concave flowering axis, in which are imbedded numerous separate fruits with dry pericarps. In the Fig the seed-like pericarps are seated on the walls of the internal cavity (fig. 305); in *Dorstenia* they are imbedded in the concave-topped common receptacle.

Fig. 305.

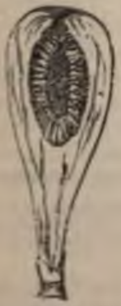


Fig. 306.

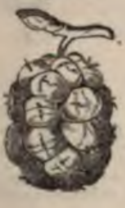


Fig. 307.

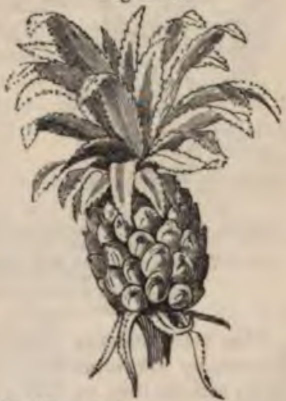


Fig. 305. Vertical section of the Fig (*Ficus Carica*).
Fig. 306. Fruit of Mulberry (*Morus nigra*).
Fig. 307. Fruit of Pine-apple (*Ananassa sativa*).

290. The *Sorosis* differs from the foregoing by the substance of the constituent pericarps, formed of the ovaries and floral envelopes of the flowers, becoming pulpy and confluent with each other (*Morus*, fig. 306), and sometimes with the succulent axis of the inflorescence (Pine-apple (fig. 307), Bread-fruit).

291. The *Strobilus*, or Cone, is the characteristic fruit of the Gymnosperms, consisting mostly of a conical or ovate mass of imbricated scales, with seeds in their axils (or on their borders, *Cycas*), each scale being the development of a single carpel, representing a female flower (*Pinus*).

292. The *Galbulus* is a kind of cone with few scales, which have their heads thickened and forming the periphery of a somewhat globular mass, dry (*Cupressus*), or sometimes succulent (*Juniperus*).

### *The Seed.*

293. The consequence of the fecundation of the ovule is the development of an *embryo* in the embryo-sac (§ 241); and during the maturation of the fruit the ovules are perfected into *seeds*, the essential character of which is, that they are independent reproductive bodies, containing an *embryo* or rudimentary new plant at the time when they are cast off by the parent (fig. 309).

Fig. 308.

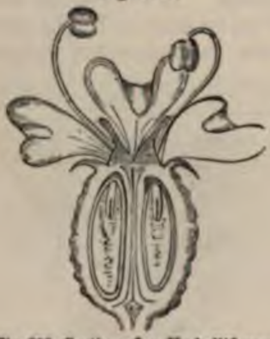


Fig. 309.

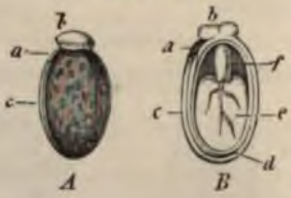


Fig. 308. Section of an Umbelliferous flower, showing the two seeds *in situ*, each containing an embryo at the upper end, imbedded in albumen.

Fig. 309. Seed of Castor-oil plant (*Ricinus*): *A*, external view. *B*, vertical section: *a*, *hilum*; *b*, *micropyle*, with an *arillode* around it; *c*, *raphe*, leading to (*d*) the *chalaza*; *e*, *embryo*, with foliaceous *cotyledons*, and *radicle* pointing to the *micropyle*; *f*, *endosperm* or *albumen*.

The seed remains attached to the placenta of the fruit, until mature, by the *funiculus* (§ 234), from which it ultimately separates by an articulation, so that a scar is left, called the *hilum* (§ 236).

294. The *direction* and position of the seeds in the cells of the fruit, as well as the modes of curvature, indicated externally by the relative positions of the hilum (fig. 309, *a*), micropyle (*b*), chalaza (*d*), and raphe (*c*), are the same as in the case of the ovule; and the same terms (§§ 237–240) are made use of in describing their peculiarities.

The face of a seed is the side or edge turned towards the placenta from which it arises.

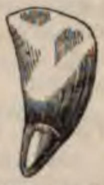
The direction of seeds may differ from that of the ovules, by alteration in the shape of the ovary, abortion of ovules, &c. It may be noted that anatropous ovules normally have the raphe *next* the placenta if *ascending* or *suspended*, so that the raphe indicates the face; but by irregular development of the pericarp this condition may be reversed in the ripe fruit, as in *Ranunculus*.

295. The seed consists of the proper *body* of the seed and its integuments, to which in some cases are added appendages of various kinds.

The body of the seed is sometimes called the *nucleus*, which leads to confusion, as it occupies the same position in reference to its integuments as the nucleus of the ovule, but is by no means always identical with it.

296. The outer coat of the seed, called the *testa*, completely encloses it, marked, however, by the microscopic orifice of the *micropyle*, and by the *hilum*, or scar of the funiculus. The testa presents the greatest possible variety of conditions of texture, from membranous, horny, woody, or bony hardness, on the one hand, to a leathery or soft, pulpy condition on the other. The dry forms frequently exhibit beautifully regular markings, such as minute ridges, reticulations (Poppy, *Silene*, &c.), spines (*Stellaria*, &c.); or the margins are produced into sharp edges or broad wings (*Bignonia*, *Pinus*, fig. 310); or it bears a crown of hairs, or *coma*, at one end, as in *Epilobium*, *Asclepias*, &c.; or it is completely covered with long hairs, as in the Cotton-plant; while in various Polemoniaceæ, Labiatæ, &c. (*Collomia* &c.) it is clothed with microscopic hairs, which expand elastically, and dissolve into a kind of mucilage when wetted. Sometimes the testa is loose, and forms a kind of sac around the body of the seed, as in Orchidaceæ, *Pyrola*, &c.

Fig. 310.



Winged seed of Pine.

The *inner integument*, the *tegmen* or *endopleura*, is not generally distinguishable; when it is, it is usually whitish and delicate.

The reference of the integuments of the seed to their elements in the

Fig. 311.

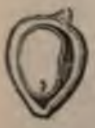


Fig. 312.

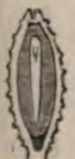


Fig. 313.

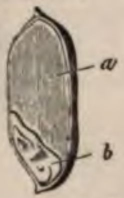


Fig. 314.

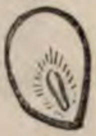


Fig. 311. Vertical section of an achænium of *Ranunculus*, showing the seed with a minute embryo in the albumen.
Fig. 312. Section of the seed of *Typha*, showing the straight embryo in the axis of the endosperm or albumen.
Fig. 313. Section of the caryopsis of Wheat, showing the abundant endosperm, *a*, with the embryo, *b*, at the base, outside.
Fig. 314. Section of the seed of *Iris*, with the embryo enclosed in the endosperm.

ovule is a subject of great complexity, since there appear to be no rules as to what regions of the ovule, from the nucleus outward, shall remain distinguishable or enter into the composition of the coats. The testa is commonly formed of the *primine* and *secundine* (§ 236) of the ovule conjoined. The tegmen seems to originate sometimes from the secundine, sometimes from the substance of the nucleus, &c. Small indehiscent fruits, such as the achænia (§ 257) of *Ranunculus* or of Labiates, are liable to be mistaken for seeds when detached; they are known by the remains of the style, and by the complete seed with its proper coat being distinguishable on opening the pericarp (fig. 311).

297. A considerable number of seeds possess a coat or appendage distinct from the proper integument, and produced *entirely during the development of the seed from the ovule*—that is to say, after the fertilization of the latter. These additional structures are frequently fleshy when mature, as in the Spindle-tree, *Euonymus*, *Podophyllum*, &c. The older authors called all the forms by the same term, *arillus*; recent authors distinguish the *true arillus*, which grows up over the seed from the funiculus, like the primine and secundine, as in *Nymphæa*, Passion-flowers, &c., from the *arillode*, which originates at or near the micropyle, and grows down more or less over the testa, as in *Euonymus* (where it forms a pulpy coat), in *Euphorbia*, *Ricinus* (fig. 309), *Polygala*, &c.

The *mace* of the Nutmeg is an arillus, adhering both to the hilum and micropyle.

The appendages which grow from the raphe, in *Chelidonium*, *Asarum*, *Viola*, &c., are sometimes called *strophioles*.

298. The body of the seed is composed either of the *embryo* alone, or of the embryo imbedded in a mass of tissue, called the *endosperm*, *perisperm*, or *albumen* (figs. 311–318). Seeds wherein the embryo is immediately invested by the integuments are commonly called *ex-*

Fig. 315.

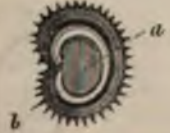


Fig. 316.

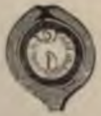


Fig. 317.

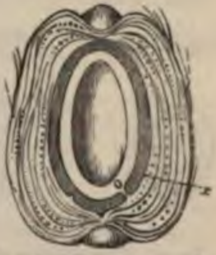


Fig. 315. Section of the seed of *Lychnis*, with a peripherically curved embryo, *b*, surrounding the perisperm, *a*.

Fig. 316. Section of the seed of *Piper*, showing the embryo in a separate sac at the apex of the endosperm, which latter is hollow in the middle.

Fig. 317. Section of the fruit of the Cocoa-nut Palm, showing the fibrous epicarp, the woody endocarp (*x*) enclosing the hollow perisperm, in which lies the minute embryo.

*albuminous* (figs. 319 & 321). Where an *endosperm* exists, they are called *albuminous* (figs. 311 &c.).

The term *albumen*, founded upon the functional analogy with the albumen, or white of an egg, is very inconvenient, as it has a distinct chemical sense, in which it is frequently used in the chemical questions of vegetable physiology; and therefore the word *perisperm* is preferable.

299. The *perisperm* varies very much in both quantity and in texture—in proportion to the relative magnitude attained by the embryo (figs. 315 & 318), and in consequence of the different mode of development of the cellular tissue and its contents in different cases.

The texture or consistence of the perisperm is termed *mealy* or *farinaceous* when it may be readily broken down into a starchy powder (as in Corn-grains &c.), *oily* when it is composed of soft tissue loaded with fixed oil (as in the Poppy and Cocoa-nut), *mucilaginous* or fleshy when it is tougher and swells up readily when wetted (as in the Mallow), *horny* when hard and more or less elastic (as in Coffee, *Galium*, *Iris*, &c.).

Fig. 318.

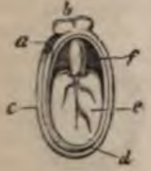


Fig. 319.

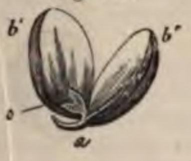


Fig. 320.

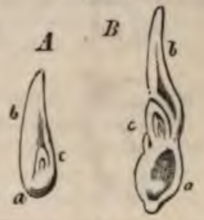


Fig. 318. Vertical section of the seed of *Ricinus*: *a*, hilum; *b*, micropyle; *c*, raphe; *d*, chalaza; *e*, embryo; *f*, perisperm.

Fig. 319. Exalbuminous dicotyledonous seed of a Bean, with the coats removed: *a*, radicle; *b' b''*, cotyledons (separated to show the plumule, *c*).

Fig. 320. Monocotyledonous embryos removed from the perisperm, vertically sliced: A, of *Calla palustris*; B, *Avena* (Oat): *a*, radicle; *b*, cotyledon; *c*, plumule.

The perisperm is usually a uniform mass; but in *Nymphæa*, Piperaceæ (fig. 316), *Canna*, and some other plants the embryo is contained in an inner central compartment or sac (sometimes called the amniotic sac), so that the perisperm is here double; the enclosed portion is sometimes called the *endosperm*; the development of this will be described in the Physiological part of this work.

The uniformity of the perisperm is also destroyed in some seeds by a peculiar lobulated condition of the outer portion, the sinuosities being filled up and enclosed in an inseparable layer of different-coloured tissue, giving a marbled appearance; this, which is seen in the Nutmeg, is called a *ruminated* perisperm or albumen. In the Cocoa-nut the perisperm is hollow when mature, containing the so-called milk (fig. 317).

300. The *embryo*, or rudimentary plant contained in the seed, ordinarily possesses, when the seed is mature, all the essential

organs of vegetation, namely root, stem, and leaves, although in a few cases the leaves are undistinguishable; while in others the embryo is a mere cellular nodule in the ripe seed, as in Orchidaceæ and Orobanchaceæ.

301. The end of the embryo pointing to the micropyle is the *radicle* (figs. 318–321 *a*) or rudimentary root, forming the lower end of the axis which terminates at the other end in the *plumule* (figs. 319–321 *c*) or rudimentary terminal bud; the rudimentary leaves, called *cotyledons* (figs. 319–321 *b″*, *b′ b*), differ in number in the two great classes of Angiospermous Flowering plants, since in the Dicotyledons there are two, placed face to face at the upper end of the axis, with the plumule between them (fig. 319); and in Monocotyledons only one exists (or the rudiment of another on a different level), and this is more or less completely rolled round the plumule, like the sheath of the leaf in Grasses (fig. 321).

Fig. 321.

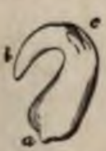


Fig. 322.

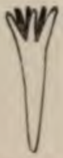


Fig. 323.

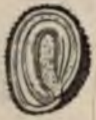


Fig. 324.

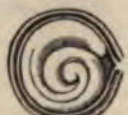


Fig. 321. Exalbuminous Monocotyledonous seed of *Potamogeton*, with the coat removed: *a*, radicle; *b*, cotyledon; *c*, plumule.
Fig. 322. Embryo of *Pinus*, extracted from the endosperm, and the cotyledonary lobes separated.
Fig. 323. Vertical section of the seed of *Atropa Belladonna.*
Fig. 324. Vertical section of the seed of the Hop (*Humulus*).

The embryos of the Gymnosperms are either dicotyledonous, as in *Cycas, Taxus, Juniperus*, &c., or really or apparently *polycotyledonous*, as in *Pinus* (fig. 322), where it is said that the seeming whorl is formed of two deeply divided cotyledons.

302. The embryo, whether covered only by the coats, or imbedded in perisperm, exhibits many varieties in the relative position of its parts: thus it may be *straight* (fig. 312), *curved, arcuate*, or *hooked* (fig. 323), *spirally coiled* (fig. 324), or *folded*; in the last case the radicle may be folded against the back of one of the cotyledons (*incumbent*, fig. 325), or against their edges (*accumbent*). The cotyledons, which are usually of fleshy texture, and vary much in form, degree of expansion, and solidity in different cases, are occasionally rolled or folded up like leaves in leaf-buds (figs. 326 & 327); and these are described by the terms defined above under the vernation of leaves (§ 113). They have sometimes quite a *filiaceous* character, as in *Convolvulus, Ricinus* (fig. 318), &c. The fleshy kinds occasionally cohere very firmly in Dicotyledons in the mature state; and they are sometimes of unequal size, as in *Trapa natans.*

In most cases the cotyledons form the greater part of the embryo; but sometimes they are very small (*Barringtonia*), while in *Cuscuta*, a leafless parasite, they are undistinguishable. The cotyledons usually decay after the germination of the seed; but in *Welwitschia* the two cotyledons are persistent, and form the only leaves of the plant throughout its life.

Fig. 325.

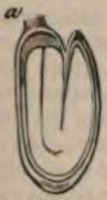


Fig. 326.

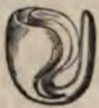


Fig. 327.

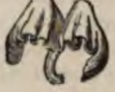


Fig. 325. Vertical section of the seed of *Erysimum*: *a*, funiculus.
Fig. 326. Dicotyledonous embryo extracted from a Turnip-seed.
Fig. 327. Dicotyledonous embryo extracted from the seed of the Maple (*Acer*).

303. The relations of the embryo to the perisperm and integuments afford some regular conditions, to which special terms are applied. With regard to the perisperm, the embryo may be *axial* (fig. 312), and then merely with its cotyledons lying against the apex of the perisperm, as in *Carex*, or completely immersed in it, as in *Polygonum*; it may be *abaxial* or *excentric*, when the layer of perisperm is thickest on one side; or it may be *external*, and then either *lateral*, as in the Grasses (fig. 313), or *peripherical* (*albumen centrale*), when it curves round the perisperm, as in *Mirabilis*, *Lychnis* (fig. 315), &c., or with the perisperm outside (*albumen periphericum*).

304. The direction of the embryo in relation to the micropyle is almost always constant, the radicle pointing to that orifice, which indicates the organic apex of the seed.

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# CHAPTER III.

## MORPHOLOGY OF THE CRYPTOGAMIA.

### GENERAL OBSERVATIONS.

305. The general distinctive characteristics of this division of the Vegetable Kingdom are:—1st, the substitution for flowers of sexual organs which, although analogous in many respects, are of very different structure from those of the Phanerogamia, and are both inconspicuous in relation to the vegetative organs, and very transitory in their existence; 2ndly, the production, by the various forms of

fruit, of the reproductive bodies called *spores*, destitute of an embryo and often consisting of simple cells, instead of seeds like those of the Phanerogamia.

306. By these characters the whole of the Cryptogamia are at once separated from the Phanerogamia, and at the same time allied together. The Cryptogamia themselves are divisible into two principal groups, characterized by the structure of their vegetative organs and the nature of their fructification. The higher group, composed of the Ferns and their allies, the Mosses, &c., are related to the Phanerogamia by the possession of an axis or stem bearing leaves and roots; and their spores are matured in special organs, called spore-cases or *sporanges*, formed from the foliar organs. The lower groups present no clearly marked distinctions between root, stem, and leaves; but their vegetative structure presents itself in a vast variety of forms, often of indeterminate mode of growth—sometimes imitating a leaf, sometimes a stem, and sometimes a root, but always composed of simple cellular tissue, and without leaves or leaf-buds. This structure is known by the name of a *thallus*, signifying a *bed* or *layer*. The simplest plants of this class consist merely of single cells. In other cases the cells are arranged in linear series, simple or branched, or in planes; and thus by stages of gradually increasing complexity the higher groups are reached. The reproductive organs have now been ascertained in so many instances to be, some analogous to the male, others to the female organs, that the existence of sexual reproduction may be regarded as general throughout the group. The spores of the Thallophyta are not produced in highly organized capsules like those of the Angiosporæ, but lobes or parts of the thallus are more or less modified to form fruits of diverse form, in which the spores are produced in more or less exposed parent cells, or *thecæ*, from which they are directly discharged when mature. The Thallophyta are likewise extensively propagated by cells (*gonidia* and *conidia*), which become detached from various points of the thallus; these, however, are analogous to *bulbels*, and not to seeds or spores. Many of them are reproduced by zoospores, or cells which become detached from the parent plant, swim about in water by means of cilia, and ultimately become developed into a thallus. In other cases, again, reproduction is effected by means of a process termed conjugation, wherein a communication between two cells is established, and the contents of the two become blended into a single spore.

The modifications, both of the vegetative and reproductive organs of the Cryptogamia, are so numerous and diverse, and so characteristic in each class, that it is most convenient to treat their morphology under the separate heads of the classes, and not of the organs themselves, as has been done with the Phanerogamia; hence further remarks on this subject will be found under the head of the several groups, and in the physiological portion of the work.

# PART II.

# SYSTEMATIC BOTANY.

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## CHAPTER I.

## PRINCIPLES OF CLASSIFICATION.

### Sect. 1. Species and Genera.

307. In the study of Vegetable Morphology we endeavour to discriminate the different kinds of organs possessed by plants, to refer to their appropriate types the infinite variety of their forms and modifications, and to ascertain the general laws under the regulation of which the diversity of actual conditions is evolved. In Systematic Botany a different problem is set. It is no longer in the separate parts or organs of plants that we seek the primary facts upon which to found our generalizations, but in entire plants possessing peculiar assemblages of morphological characters. Our object is, in the first place, to establish analytically our elementary facts in the rigid definition of the distinct kinds of plants; and, in the next place, synthetically to generalize them, by gathering the kinds into classes, according to essential agreements among themselves, which classes then become types of the Vegetable Kingdom, and illustrations of the physiological and morphological laws ruling the existence of plants.

Just as in morphology the study of the special forms of organs in detail must precede the formation of a clear general conception of each kind of organ, so the study of individual kinds of plants must precede the formation of clear ideas respecting classes or aggregates of plants. But, on the other hand, as the establishment of morphological principles facilitates the discovery of the true signification of organs of unusual character, the establishment of philosophical principles of classification leads to the recognition, not only of the relations of obscurely characterized *kinds* of plants, but of the relative importance, in a systematic point of view, of the different characters by which the particular kinds of plants are distinguished.

These considerations indicate the main distinction between what are called *Artificial* and *Natural* Classifications. In the former, the only object is to arrange or place objects in such order that we may find them readily by some prominent mark, in the same manner as words are arranged alphabetically in a dictionary. In Natural Classification, the object is so to combine our materials that the things brought closest together shall have the greatest possible agreement; from which it results that a knowledge of all the peculiarities of one carries with it the knowledge of *most* of those of its neighbours, and enables us, from the observation of a portion of the characters of a given kind, to foresee the rest, or at all events to determine the limits beyond which it cannot vary—in the same manner as we conclude from our knowledge of a noun substantive as to the meaning of the derivative verb, with its adjectival participles, &c.

308. Systematic Botany is founded upon the recognition of the existence of distinct *kinds* of plants—a notion which of course belongs not to science exclusively, but is a part of the common experience of the world. But there is a great difference, practically, between the kinds of things accepted in the ordinary affairs of life and the kinds admitted in science, more especially in the Biological sciences. The idea of a *kind*, or, as it is termed, a species, in Botany and Zoology, is a conception which has something peculiar to itself as part of these sciences—and is not only rigidly defined, but its definition is made to depend upon considerations of the widest generality.

309. We may adopt, from universal experience, the assertion that the Vegetable Kingdom consists of plants of a vast variety of forms, and, further, that we meet with more or less considerable numbers of individual plants possessing similar forms, or undistinguishable from one another by any differences except those of size, height, and the like. In common language, we connect together all such similar forms under one name, saying they are all of one *kind*; this simple abstraction is a rough exemplification of the naturalist's *species*. But science requires that the ideas upon which it builds should be firmly established and accurately defined. Now it will be commonly found that the notions of the distinction of kinds held by ordinary persons are totally deficient both of fixity and generality; and if inquired into, they will be discovered to rest upon arbitrary, and often even upon false grounds. Hence the naturalist, admitting the general fact of the existence of kinds, seeks for something more fixed, more essential, by which to define the idea, to serve as a guide and rule in obscure cases, and as a means of establishing among the cultivators of science that agreement upon fundamental propositions which is indispensable to the advancement of knowledge.

310. We have admitted the common notion of kind, as founded on resemblances. There is another fact of daily experience which is no less important in reference to this point; that is, the circumstance that plants produced from seeds most commonly resemble in

all important respects the parent plant from which the seeds are derived, and this through an indefinite number of generations; from which it follows that kinds or species of plants are regularly reproduced by their seeds.

311. According as we attribute greater weight to one or the other of these departments of experience, we shall bring forward most prominently one or the other of the two most important of the characters by which the idea of a species is defined. 1st. A species consists of all those individuals which agree in all their important characters, in the same way as do individuals of analogous structure, which we know to have descended through a number of generations from a common stock. 2nd. A species consists of all those individuals which have been produced through seed from an original individual, or pair of individuals, of a distinct kind; or, to put it less hypothetically, a species includes all the descendants of an indeterminate number of progenitors which did not differ from each other in any characters which are constant in their progeny. To these may be added the assertions that individuals of the same species may be cross-fertilized, to the improvement rather than the detriment of the fertility of their seeds, and that they are affected in a generally similar manner by external agencies.

It must be repeated here that the whole object of these definitions is to make clear and precise a notion derived directly from general experience, and not merely to set up an imaginary or metaphysical conception which is not realized in nature. Species, on this view, actually exist; for every individual represents the species to which it is referred, and can only differ from the description applied as characteristic of it in possessing certain additional, unimportant peculiarities, which may be passed over when considering this individual in the light of a representative of its species.

Diversity of opinion still exists among naturalists as to the origin and fixity of species. On the one hand it is assumed that every distinct species has originated in a distinct creation of that form, which has been perpetuated, with the essential characters unchanged, through succeeding generations. It is usually added by the same school that, as regards plants, every species has originated from a single prototype, or a pair of parents where the plant is diœcious.

It is of some considerable importance whether we suppose the prototypes to have been singly created or in numbers, since, as has been acutely observed, the admission of a number of simultaneously created prototypes gives the possibility of certain *varieties*, or *races* as they are called, being aboriginal, like the species itself; while extension of the original creation may also be carried so far as to contradict not only the assumption of what are called original centres of diffusion of species, the basis of most of the generalizations of Geographical Botany, but also the hypothesis of the single origin of species in time, which is necessary to all palæontological arguments respecting the relative age of geological formations.

On the other hand, it is contended by some writers that species are not all aboriginal; and this notion involves the conclusion that they are not absolutely invariable, and the developmental doctrine is thus adopted, often indeed in a modified form, by the supposition of the creation of a certain number of prototypes, from which, under the influence of varying external agencies, the multiplied forms have, in the course of long ages, been evolved,—an assumption less warranted by experience than the assertion of distinct creations. In adopting the hypothesis that species are invariable, and that the prototype or prototypes were created at one time and in one place, we believe that we accept the view supported by the preponderating amount of evidence, which is necessarily scanty on both sides. And what appears to us still more important is the fact that we here take up a principle which is far more fruitful in conclusions leading to a lucid and consistent view of the creation.

Mention has been made of modifications of individual representatives of species, under the name of *Varieties*. We have stated that species are distinguished by their constant characters, but that individuals may possess other *additional* characters of less importance, which are inconstant. Even as in the human species we find every individual possessing certain peculiarities, so even in almost to the lowest of created beings do we find what is called an idiosyncrasy, and individual character, chiefly depending, in the vegetable kingdom, upon the conditions under which they have grown up. We often find seeds from the same parent producing individual plants differing in the colour, size, and number of their flowers, and of their vegetative organs, according to the conditions of climate and soil to which we submit them. Very often, moreover, we find these differences displaying themselves under what appear to us identical conditions—as is particularly the case with many of the favourite "florists' flowers," such as the *Pelargonium*, *Fuchsia*, Pinks, Asters, &c., which "sport" out into numberless varieties when raised from seed under highly artificial conditions. The occurrence of such variations is less common, and, when it occurs, generally less marked in wild plants; which might naturally be expected, from the likelihood of wild plants' maintaining their footing best in a position where the conditions are most natural to them; but we do find remarkable cases of variation in many wild species, as of colour in the common Milkwort and the Columbine (*Aquilegia*); but most of those kinds which exhibit the tendency now and then in a wild state, become extremely variable under culture. Some of the variations are dependent simply upon modifications of the cell-contents of certain tissues, as in the commonest of all variations, those of colour, and in the not uncommon appearance of white patches and streaks ("variegation") on the leaves. Other variations are teratological, and result from the over-stimulation of the vegetative system, causing the reproductive organs to degenerate (of which the ordinary "doubling" of flowers by the degradation of their stamens into petals is an example)—or, *vice versâ*, the application of stimuli at particular epochs, producing remarkable development of flower or fruit. All these variations, more especially those involving serious teratological changes, tend to disappear. Common variations, of slight importance, mostly die out at once in the descendants through seed, especially if the conditions are varied; serious departures from the typical structure (teratological variations) lead to barrenness and incapability of continuing either the variety or the species by seed.

It is important to note here a fact which will be more minutely examined in another place, namely, that although the peculiar characters of varieties are commonly lost in seeds, the peculiar form is capable of indefinite propagation by vegetative multiplication through cuttings &c., the special idiosyncrasy being possessed in common throughout all the leaf-buds, both while forming part of the parent and after they have been detached from it to form new plants, grafts, &c.

A certain number of species which vary more or less in a wild state, exhibit a remarkable peculiarity under systematic cultivation. By strictly maintaining a certain set of conditions, varieties originating accidentally or through intentional treatment are made to manifest their additional peculiarities so strongly, that they transmit the tendency to present similar peculiarities to their seeds; and such transmission goes on for an indefinite number of generations, provided the requisite external conditions are kept up. In this way arise what are called *Races*, series of individuals connected by common characters and by generation, like species; but, unlike them, liable to lose, in one or a few generations, under change of conditions, part or all of the essential characters by which they are distinguished. We have examples of such races in most of our esculent vegetables, especially in the many varieties of form, more or less permanent, derived from the wild Cabbage (*Brassica oleracea*).

These, together with *Hybrids*, or the produce of cross-fertilization between individuals of distinct species, will be referred to again among the phenomena of the Physiology of Reproduction. The determination of the limits of species is greatly obstructed in many cases by the frequent occurrence of varieties, and more particularly of races—to which hybrids add another complication, probably of less importance than many modern authors suppose. It appears probable that the number of real species is far smaller than is usually supposed, and that many races, and a large number of frequently recurring varieties, hold a place in our existing lists of species.

312. In the foregoing paragraphs we have endeavoured to define and explain the universal idea of species, or kinds, in its peculiar acceptation in natural history, more particularly in Botany. *A species includes all the individuals that agree in all their constant characters.* If distinct species exist, it is clear that they, on the other hand, must *differ in their constant characters.* But whenever we examine a large assemblage of distinct species, we shall find that certain of these agree with certain others more closely than with the rest; so that we may parcel them out into groups, in each of which we shall find an agreement in a number of common characters, by which it is also distinguishable from the other groups. Generally speaking, we shall find that we can place together a number of species agreeing closely in the essential plan of construction of their *floral organs*, while they differ in the forms and duration of their *vegetative organs* &c. Groups of this kind are called *genera*; and the notion of a *genus*, like that of species, is not only common to all departments of human knowledge, but it is also existent

in the language of common life in its special natural-history sense, only requiring for scientific purposes to be more strictly defined. In every language we find *generic* names applied to plants, such as Willow, Rose, Violet, and a hundred others, each of which terms is indicative of a group of kinds or species, more or less extensive in different cases, corresponding exactly in its logical value to the *genus* of the botanist.

Some of these groups are characterized by very striking peculiarities, so that even the genera of vulgar language correspond very nearly with those of the botanist; but in the generality of cases the popular collective names are applied on superficial grounds of resemblance, and include widely diverse species. For example, the term Violet is made to bind together not merely the common scented and other true Violets, but the Dame's Violet (*Hesperis*), a plant of the Cabbage family, the Calathian Violet (*Gentiana Pneumonanthe*), a true and characteristic Gentian, the Dog's-tooth Violet (*Erythronium Dens-Canis*), a plant of the Lily family, &c.; while the term Rose is extended from true Roses to *Cisti*, or Rock-roses, Rhododendrons, Alpine Roses, &c. Still some real genera are characterized in a sufficiently marked way for most of their constituent species to be recognized as such pretty readily, after a very small amount of attentive examination, as, for example, true Roses, Willows, Pinks, &c.; and we call such genera, including species of a very marked similarity, "natural genera" *par excellence*. On the other hand, the principle of combination which accords with the intuitive classification in those natural genera leads to the establishment of other genera wherein the species seem at first sight to differ widely, of which we could not have a better example than in the genus *Euphorbia*, where our native species are inconspicuous herbs, while the tropics afford species with large spiny Cactus-like trunks, &c.

Moreover the carrying out of the same principle leads in certain cases to the generic separation of species which present close agreement in their general characters, but are distributable into a number of groups characterized by very decided morphological diversities in important parts of their floral organs. Thus, in the Umbelliferæ, the Compositæ, the Grasses, and some other families, we separate generically species which have a great resemblance in the majority of their characters. This happens especially in what are called *very natural families* of plants, large assemblages of genera evidently connected with each other by the presence of some very marked peculiarity, such as the Umbelliferous inflorescence, the Papilionaceous corolla of the Leguminosæ, the Capitulous inflorescence of the Compositæ, the peculiar spikelets in the Grasses, &c. On the other hand, the "natural genera" occur mostly where the character of the natural family is more lax and flexible, as in the Ranunculaceæ, Rosaceæ, &c.

In the present state of knowledge, it must be admitted that a large portion of our generic distinctions are somewhat arbitrary, and that the species included in some genera agree together much more closely than those combined under other generic heads. At the same time it cannot be doubted that some genera are really far more extensively represented by species than others; so that the mere number of kinds included in a genus is to be totally neglected in a natural classification; and many recent authors have done disservice to science in general by splitting up large natural genera on slight characters for the convenience of systematists. It is far more instructive to keep together the members of large natural genera, like *Ficus*, *Erica*, *Begonia*, &c., than to subdivide them under names which disguise their relations; and the convenience of systematists may always be sufficiently regarded by the establishment of *sections* in extensive descriptive works.

313. *Genera* are groups of species associated on account of agreement in the essential characters of their floral organs; but here, as elsewhere in nature, variations from our abstract types must, to a certain extent, be admitted. Some undoubtedly natural genera include species with their floral organs varying in certain particulars more than is usual in groups associated under a common type, somewhat as certain species admit of a wider range of variation than others. Here, again, physiological characters become of value; and as in species we regard the fertility of the seeds produced by unlimited cross-breeding between the varieties as a proof of these being individuals of the same species, so with regard to genera it is commonly held that a generic connexion between diverse species is indicated by the capability of producing *hybrids* by cross-breeding. These true hybrids produced between distinct species of the same genus are barren, or can only breed with individuals of one of the parent species, which soon eliminates the cross, and leads to a complete reversion to that species.

This physiological test is consonant with morphological evidence. Individuals of the same species are capable of indiscriminate fertilization because they are exactly alike in all essentials of structure. In hybrids produced between two species of a genus, the parents agree sufficiently in structure to allow of their producing a few fertile seeds, but the plants raised from these seeds contain two contradictory impulses, which so far prevent the perfection of their organization that they remain barren.

314. [The above remarks on the nature of species were penned before the publication of Mr. Darwin's work on the 'Origin of Species.' It is of course impossible to say to what extent, if at all, Professor Henfrey's views on these points would have been modified by the publications of Darwin, Herbert Spencer, Wallace, and other advocates of what is termed the hypothesis of the derivative origin of species; hence it has been deemed preferable to retain Professor Henfrey's opinion as above expressed, without addition or modification. It is nevertheless desirable to state succinctly the views now held by a large number of naturalists as to the origin and progress of the aggregates or forms called species. Assuming, then, the existence at this present epoch of certain aggregates of individual plants which may conveniently be called species, these species are, on the derivative hypothesis, supposed to have originated from other preexistent species, and these again from others; so that in the beginning, it is surmised, there

were but a very few primordial forms, from which all existing species have been derived, just as individuals may be traced back to a common parent stock.

Supposing species to have originated in this way, the question then arises as to what causes have produced the modifications. Where, on this hypothesis, there were originally a very few, or perhaps a single primordial form, to which all then existing individuals might be referred, there is now an infinite number of forms both in the animal and vegetable kingdoms. How have these forms arisen? To this question the answer given by various naturalists has been different.

By some the variations have been attributed to the influence of external conditions; by Darwin to an innate tendency, producing variations of structure, some of which, under given circumstances, would be favourable to the progress and development of the individual, and others not so. In the battle of life, the struggle constantly going on in animated nature, those variations most advantageous to the organism in its competition with others would be preserved by "natural selection," while other variations of less advantageous character would be obliterated or not perpetuated. Hence the victory would be to the strongest, the weakest would go to the wall, and the result would be, in Mr. Spencer's language, "the survival of the fittest." It will thus be seen that on this hypothesis species are not considered immutable, and variations, especially such as are advantageous to the organisms, are regarded as the starting-points of new species. With reference to these points the student will do well to bear in mind that these and kindred speculations are not to be treated as dogmas or creeds, but as means to an end, and that end the more perfect knowledge of the origin and relation of existing forms. Any hypothesis or theory which will serve to correlate and bind together a number of otherwise isolated facts and explain their interdependence, is valuable not only for what it effects at the time, but as a focus around which other facts may in future be gathered. That hypothesis is best which serves to give a rational explanation of the largest number of observed phenomena of the greatest importance. Tried by this test, the Darwinian hypothesis, or, rather, the theory of evolution, has great advantages, and presents on the whole fewer difficulties and less inconsistencies than the older hypothesis of separate creation of each species. Particularly does this seem true in the case of the subject now before us—the classification of plants. The admission of the principle of filiation and genealogical descent gives the natural system of classification a clearer claim to its title of "natural" than it had before, supplies the explanation of a vast number of phenomena otherwise inexplicable, and offers plausible and valid reasons for the existence of facts and processes that were previously considered either unintelligible or purposeless modifications of an assumed structural type. The portion of Mr. Darwin's hypothesis which has perhaps received the least amount of assent has been that relating to natural selection. The idea was based on that artificial process of selection by means of which man has been enabled progressively to improve and perpetuate the different forms of domestic animals and cultivated plants. In the latter case the horticulturist is ever on the look-out for variations. If he sees one that suits his purpose, such, for instance, as a form producing larger flowers than ordinary, he does all that he can to perpetuate that variety by carefully selecting seed from it, at the same time that he destroys or neglects other less desirable variations. In this manner, after a time, the selected variety becomes "fixed," and a "race" is formed. On the Darwinian hypothesis a selective process is supposed to occur naturally, similar to that employed by the gardener or agriculturist as just explained, such selection or elimination resulting, as before said, in the survival of the fittest.]

## Sect. 2. NOMENCLATURE.

315. The Terminology of Botany establishes exact rules for naming the parts or organs of plants, and the different characteristics which those organs present. Nomenclature deals with the naming of plants themselves as members or parts of the Vegetable Kingdom; and it furnishes the rules for naming the kinds of plants, and the various groups or assemblages in which they are associated in our systematic classifications of kinds.

Common and striking plants possessed names before the Science of Botany existed; and the earlier botanists adopted those names; but the natural result of minute investigation has been, on the one hand, to prove that different things were often confounded under one name, and, on the other, to ascertain the existence of multitudes of plants previously unknown, and for which no names existed. For a long period the wants of botanists in this respect were supplied somewhat irregularly—either by associating characteristic adjectives or descriptive sentences with existing names, or, where a decided generic distinction was manifest, by the invention of new names, which laid the foundation of a purely technical nomenclature.

It has been remarked in a preceding section that the groundwork of the scientific idea of a genus exists in common language; and we find that names applied to collections of kinds abound in the languages of all races of men which have made any considerable progress in intellectual culture. In most, if not all, languages there is a strong tendency to give them a substantive value, and to separate the included species by adjectival qualifying names. It is true that these generic substantives must be founded in the first instance on the observation of a simple kind; but, in the imperfection of early observation, the term is extended by generalization long before the peculiar characteristics of the included species are clearly discriminated. Hence we find the majority of the plants named in the oldest writers, and in the language of common life, designated in the first place according to supposed generic characters, and only secondarily according to specific differences.

316. Botanists accept the rule of nomenclature given by common language, which makes the generic name the basis of the name of all species. In respect to this, then, interference is restricted to the clear distinction and rigid limitation of groups which are combined under generic names.

317. In respect to species, however, it was long ago found that no mere modification of the rules of ordinary language would suffice to bring the nomenclature of plants into that definite and simple condition which is one of the primary conditions of scientific progress; and the immortal Linnæus, who effected such a fruitful revolution in descriptive natural history by the establishment of a fixed and rational terminology, furnished one of the most valuable instruments for the promotion of philosophical natural history when he propounded the now universally adopted scheme of the *binomial nomenclature*. Departing from the inconvenient and illogical principle that the name of a thing should be a description of it, he carried out the method of abstraction from the *genus* to the *species*, and made a single word serve the purpose of a sign at once of specific value and of specific peculiarity.

The primary rule in botanical (and zoological) nomenclature is, that *every species shall have a particular name, compounded of a substantive and an adjective* (or substantive used adjectively), *whereof the former indicates the genus, and the latter the species.*

This rule of naming may be compared with the common usage of surnames and christian names, the former indicating the family to which a man belongs, while the latter admits of his being spoken or written about without the necessity of adverting, except for special purposes, to his personal peculiarities or his relationship to the other members of his family.

318. These scientific names of plants were originally established in Latin, because Latin was the general language of science at the time they were introduced, and they will be retained with advantage so long as diversity of language exists, since they ensure to all plants and animals names which have universal acceptation, and which, like the Arabic numerals 1, 2, 3, &c., are equally comprehensible to the educated of all nations.

With regard to what are called "vulgar" names of plants, much stress is laid by some writers on the desirableness of possessing a name in the ordinary language of each country. It seems to us that while a real advantage exists in ascertaining the scientific value or synonym of the vulgar names which from long use form a real part of a language, none is gained by making fresh names, by translating the Latin names or otherwise, for species not previously recognized by ordinary persons: the use of such pseudo-vulgar names in poetry or other imaginative literature is equally pedantic and inharmonious with that of Latin terms; and where exact ideas are to be communicated, the technical Latin names are less equivocal, and generally preferable on the score of brevity and simplicity.

If all generic names were significant of striking peculiarities, more might be said in favour of translated names; but such is not and cannot be the case, and hence the slight amount of information possible to be conveyed in this way to the uneducated should not weigh at all against the enormous inconvenience and confusion which would occur to science from the adoption of a complete set of vernacular synonyms for general use in each language. Sufficient inconvenience is felt in this respect by foreigners, from the favour with which a pure and idiomatic vernacular terminology and nomenclature is regarded by German naturalists, to serve as a warning to those who would introduce it elsewhere.

319. The substantive names of genera have been and are still formed very arbitrarily, and without any generally recognized principle.

All those which have been identified as known to the ancients are called by their classic names, such as *Prunus*, *Myrtus*, *Quercus*, *Thymus*, &c., the etymology of which is more or less obscure in various cases. A very large proportion of modern generic names are founded upon combinations of Latin and, more particularly, Greek words indicating some obvious external peculiarity, or some property possessed, or supposed to be possessed, by the plants; but the application of this principle has often been carried out without accurate knowledge, and without happiness in selection, so that many such names are but little characteristic, and would often apply more correctly to other genera. Those, on the contrary, which are well chosen afford a certain assistance to the memory; examples of such names, founded on structure, occur in:—*Lithospermum*, so called from its stony fruit (or supposed seed); *Campanula*, from its bell-shaped corolla; *Sagittaria*, from its arrow-shaped leaves, &c.: on qualities, in *Glycyrrhiza* (Liquorice), from its sweet rhizome; *Rubia* (Madder), from yielding a red dye; *Lactuca* (Lettuce), from its milky juice, &c.: or on accustomed station, as *Arenaria*, *Epidendrum*, &c.: others have derived their names from supposed medicinal powers, such as *Pulmonaria*, *Scrophularia*, &c.

Another large class of generic names is founded on proper names either of mythological or real personages, more especially distinguished botanists, to whom the genera are dedicated. Linnæus drew largely upon classical mythology and legendary history as a ready source of diverse names for the many newly defined genera he had to deal with; and the names *Iris*, *Artemisia*, *Amaryllis*, *Narcissus*, &c. stand out strongly in their euphony from most of those founded on modern names; such names, however, as *Linnæa*, *Lobelia*, *Dioscorea*, *Magnolia* go far to rescue the principle of naming genera after botanists and their patrons from the opprobrium brought upon it by such as *Schumacheria*, *Schweyckherta*, *Razoumowskia*, *Eschscholtzia*, and the like, and will probably be preferred by most persons even to such "characteristic" names as *Pleuroschismatypus*, *Orystophyllum*, *Pachypterygium*, *Glischrocaryon*, &c.

In face of these last, the pseudo-Latin barbarisms *Thea*, *Coffæa*, *Bambusa*, which preserve the original native names of plants, become no longer uncouth.

320. *Specific names* are always either *adjectives*, or *substantives used adjectively*. When they are adjectives, they must of course be made to agree with the substantive; and it may be recalled to recollection that in Latin all names of *trees* are *feminine*, whatever may be the termination.

In the majority of cases, the specific names are selected on similar grounds to the generic. Attempts are very commonly made to render the name characteristic, a proceeding which in many cases affords a certain advantage; but when, on the contrary, it is carried out in imperfect acquaintance with the species of large genera, it leads to confusion. Sometimes these names indicate the character of the *leaves*, as in *Tilia grandifolia* and *parvifolia*, *Mentha rotundifolia*; or the existence of a definite number, as in *Platanthera bifolia*, *Paris quadrifolia*, &c.; or the character of the *inflorescence*, as *Butomus umbellatus*, *Bromus racemosus*, &c. Or the "habit" of a species is indicated by such adjectives as *major*, *minor*, *pusillus*, *nanus*, *gracilis*, *scandens*, &c.; or its duration, as by *annua*, *perennis*, &c.; and in some cases comparisons with other plants are marked, as in *Ranunculus aconitifolius*, *Acer platanoides*, &c.

Generally speaking, the colour of flowers is too variable for specific distinctions; but nevertheless many species are named from their usual or constant colour, as *Gentiana lutea*, *Lamium album* and *purpureum*, *Digitalis purpurea*, &c.

Station, *i. e.* kind of soil or place inhabited by a plant, is another source of names, as *arvensis* (common on ploughed land), *agrestis*, *hortensis* (on cultivated ground generally), *pratensis* (in meadows), *sylvestris* or *sylvaticus* (in woods), *palustris* (in swamps), *aquaticus* (in or about water), and *sativus*, a term commonly applied to kinds regularly cultivated from seed. Most of these terms are applied vaguely, and a similar want of accuracy in the implied idea affects many of the names founded on the places where plants have been first observed, such as *Silene gallica*, *Stachys germanica*, *Genista anglica*, &c., none of which are peculiar to the countries named, though they may, in the first instance, have been considered to be so.

Such names as *odorata*, *suaveolens*, *fœtida*, &c., expressing marked qualities, were formerly much used; and the adjective *officinalis* is found applied to a host of plants formerly valued by the herbalists for some supposed medicina. or economical property.

Substantive names used adjectively are mostly names of abolished genera, retained in association with the new generic term, as *Ranunculus Flammula*, *Pyrus Malus*, *Matricaria Chamomilla*, *Prunus Cerasus*, &c.,—these old generic terms being in a few cases double, as *Adiantum "Capillus-Veneris,"* *Lychnis "Flos-cuculi,"* &c. Or substantive proper names are used in the genitive case, as *Limnocharis Humboldtii*, *Viola Nuttallii*, *Galium Vaillantii*. The dedication to distinguished persons may, however, be effected by adjectival terms, as *Salix Doniana*, &c., the use of the genitive noun being more strictly appropriate when it is the name of the discoverer or first describer of a species, the termination *anus* conveying a mere compliment and not necessarily implying that the person to whose name it is affixed had any thing to do with the particular plant in question.

321. If the rules of scientific nomenclature were strictly enforced under the direction of a single authority, each plant would have but *one* name (composed of the generic and specific appellations), and this name would be indissolubly and unequivocally connected with the idea of the peculiar species. But it happens practically that such is not the fact, and this for reasons necessarily affecting various cases. Not unfrequently it happens that a plant possesses more than one *specific* name, which may arise from an author naming it a second time, through entire ignorance of its having been previously observed, or from his erroneously supposing a particular form to be distinct from the already known and named species. Almost as frequently in the present day do we find a distinctly recognized species denominated by more than one *generic* name, while the specific appellation remains the same, this ambiguity arising from difference of opinion as to the limits of genera, and consequently as to the group to which particular species are to be referred.

To ensure accuracy, therefore, it becomes necessary, whenever the name of a plant is mentioned in a scientific work, that the *authority* for the name (that is, the author who originated it, or whose peculiar application of it we adopt) should be indicated. This is done by subjoining an abbreviation of his name. Thus, *Bellis perennis*, Linn., or L.; *Inula Conyza*, DC.; *Pulicaria vulgaris*, Gaertn., signify that we mean the species which were defined under those names by Linnæus, DeCandolle, and Gaertner, respectively. In like manner it is requisite, in the majority of cases, where the name of a genus is mentioned, to indicate the authority, since many of the older genera of Linnæus and others have been broken up into a number of groups, and the original name restricted to one of these more limited assemblages.

322. The superfluous or incorrect names which exist in many cases cannot be neglected where they have once acquired a certain currency, because a certain amount of existing knowledge is connected with these names in the works of the writers who have used them. Hence arises the necessity of enumerating the *synonyms* of plants. The citation of synonyms is of course unnecessary in general cases, where the names of plants are incidentally mentioned, so long as the authority for the name is given; but in Systematic works, such as Descriptions of the plants of a country or province, or Monographs upon particular groups of plants, it is part of an author's duty to ascertain and indicate all the names which have been applied to the particular forms, and the exact senses in which different names have been employed. The synonyms subjoined to a specific name may indicate :—1, that the same species has received different names from different authors; 2, that a selected specific name includes the several supposed or real species enumerated under

it; 3, that the species has been removed from a genus to which it was formerly referred; 4, that a particular view is taken both of the generic and specific value of a plant concerning which opinions have varied in both particulars.

The following examples may serve to illustrate this:—

1. The name *Galium verum*, L., has simple priority, and therefore preference over *G. luteum*, Lamarck, indicating the same species, which was accidentally or erroneously named by the latter author *after* Linnæus had given it an appellation.

2. *Agrostis alba*, L., includes *A. compressa*, Willd., *A. gigantea*, Roth, *A. stolonifera*, L. (in part), &c.; these latter have been mistakenly separated from it or subsequently named without knowledge of the identity.

3. *Castanea vulgaris*, Lam., is now substituted for *Fagus Castanea*, L., as the genus *Castanea* is now regarded as distinct from *Fagus*. In many cases we find a distinct generic name given as a synonym where it is really more recent, but is rejected in favour of the older on the ground that the more recent generic separation is not approved of; for instance, *Apargia autumnalis*, Willd. (*Oporinia autumnalis*, Don).

4. *Catabrosa aquatica*, Beauv., is named in diverse works *Aira aquatica*, L., *Molinia aquatica*, Wibel., *Poa airoides*, Koel., *Glyceria aquatica*, Presl, &c.

The multitudinous synonyms which fall under the last category are attributable to the excessive tendency of modern writers to multiply genera on slight grounds. Such minor subdivisions are far better restricted to extensive systematic works, on the plan adopted in DeCandolle's "Prodromus," providing them with sectional names for the exclusive use of systematists, and preserving the more general name for common purposes.

323. The varieties of species are noticed in descriptive works when of frequent occurrence, and then are either simply indicated by the letters of the Greek alphabet, or have an additional adjective name like the species, which plan is especially followed in lists of garden varieties. In such cases either the ordinarily occurring form is taken as the type, and the series of occasional varieties begun with β, as—

*Sambucus nigra*, L. ——, var. β. leaflets laciniated (Hooker & Arnott).

or, *Sambucus nigra*, L. —— β. *virescens* (fruit green). —— γ. *leucocarpa* (fruit white). —— δ. *laciniata* (leaflets laciniated). —— ε. *variegata* (leaves with white streaks), Koch.

Or if the species is variable and no one form is considered typical, the series begins with α, thus:—

*Fedia dentata* (Hooker & Arnott). —— α (*Valerianella Mon-*

*sonii*, DC.). —— β (*Fedia mixta*, Vahl). —— γ (*Fedia eriocarpa*, Rœm. & Sch.).

The nomenclature of cultivated plants is fruitful in examples of named varieties in large numbers belonging to particular species, such as *Clarkia pulchella alba*, *C. pulchella rosea*, &c. &c.; but these names are often applied without scientific exactitude.

324. *Hybrids* are named according to certain rules when they occur frequently wild or, if obtained artificially, when they are propagated by cuttings, bulbs, &c. The names of the two parent species are combined, thus:—*Verbascum nigro-Lychnitis*, a hybrid between *V. nigrum* and *V. Lychnitis*. With regard to artificially produced hybrids, it is possible to indicate the parentage with more accuracy, and the name of the seeding-plant stands before that which yields the pollen, as *Amaryllis vittato-reginæ*, the form produced when the ovules of *A. vittata* are fertilized by the pollen of *A. reginæ*, and *vice versâ*. Where a plant is known to be of hybrid origin, it is a good plan to indicate the fact by prefixing × to the name.

325. The nomenclature of the groups above genera is of less importance than that of genera and species, and is dealt with more independently by individual writers. Artificial groups are generally named from the character on which they are founded, as in the case of the Linnean classes and orders, which will be explained in a subsequent section. The same is the case with the artificial divisions which are used in most Natural Arrangements for conveniently subdividing large assemblages of Families or Orders, such as *Thalamifloræ* &c. of De Candolle, *Polypetalæ* &c. of Jussieu. But as the essence of the Natural Arrangement of plants lies in the combination of forms according to the majority of points of likeness, or general character, we are not necessarily restricted by any definite character in the selection of the name; and in regard to the Natural Orders, great diversity of principle has prevailed in the application of the names, and even considerable latitude in the form given to them. There exists, however, one rule applied in all Latin naming of what are termed Natural Orders: the word *plantæ* is *understood*, and an adjective name agreeing with this represents the group. In existing systems we find these adjective names founded sometimes on a prevalent character in the family, as (plantæ) Leguminosæ, Coniferæ, Umbelliferæ, &c.; sometimes on the names of typical genera, as Rosaceæ, Solanaceæ, Convolvulaceæ; sometimes on an existing general name derived from common language, as Graminaceæ and Palmaceæ. A difference of termination exists even in regard to the same word in different authors: thus, one author writes Cistineæ, another Cistaceæ, with the same meaning; while others use the word Aroideæ in preference to Araceæ, or Palmæ in preference to Palmaceæ.

Attempts have been made to reduce all these names to a system, and to preserve the same form of termination for groups of the same value. Thus it is proposed to make the names of all Orders end in *aceæ*, like Ranunculaceæ, Ericaceæ, &c., the only objection to which is the necessity of discarding many familiar and well-established names, and replacing them by strange ones, as Apiaceæ for Umbelliferæ, Fabaceæ for Leguminosæ, &c. "Classes" or "Alliances" again are made alike by using the terminal form *-ales*: as Glumales, instead of Glumaceæ or Glumiferæ, for the group composed of the Orders with a glumaceous perianth, &c.

326. A fixed rule does exist among all modern writers in the denomination of *suborders* or *tribes* into which Orders are divided; for these are founded on typical genera, the names of which are made to furnish adjectives by the substitution of *eæ* for the last vowel and whatever may follow it: for example, in the Order of the Ranunculaceæ, we have the tribes *Anemoneæ* from *Anemone*, *Ranunculeæ* from *Ranunculus*, *Helleboreæ* from *Helleborus*, &c.; and in botanical works these names of tribes are commonly printed in *italics* like those of genera and species, while the names of families and all above them are printed in roman letters.

The names applied to the larger divisions of the Vegetable Kingdom in Natural Arrangements are generally made as characteristic as possible; but, as will be shown in the Section on Natural Arrangements, none of the single characters of such groups are absolute, and therefore no name founded on one character can be universally descriptive. Thus the name Monocotyledones is applied to a most natural group, in which are, however, included one or more Orders, as the Orchidaceæ, in which the embryo has no cotyledons. And it may be said that to an advanced student it is far more beneficial to regard all names as abstract signs, used rather to indicate certain plants or groups of plants with which he is acquainted, than as expressive of the characters of the plants to which they are applied.

These observations on the nomenclature of the Orders and higher groups of plants are placed here for the sake of connexion with the remainder of the subject; but they will be better appreciated after acquaintance is made with the illustrations of them in succeeding Sections.

## Sect. 3. Description of Plants.

327. It is the business of every botanist who distinguishes and names a new species of plant to furnish an exact statement of the characters by which it may be recognized by others.

The most complete fulfilment of this requisition is supplied in what is termed a *description* of a plant, in which is given a detailed account of the external form, the arrangement, and relations of all its organs, according to a fixed plan, and in a fixed language, furnished by the terminology made use of in Morphology.

In order to impress upon the mind of the student the principal points to be looked to in describing a plant, and thus to ensure completeness and accuracy of observation, we subjoin a list of the more salient characteristics which it is desirable to notice in writing a full description of a plant. Some of these are of much greater importance than others, inasmuch as they afford the means of grouping plants into genera, orders, &c., and furnish what are called *diagnostic characters*. From their great importance, much stress is deservedly laid on them; hence, after enumerating the principal "characters" necessary to be ascertained in drawing up a full description, we shall insert illustrations of the "schedules" introduced with so much success for teaching-purposes by the late Professor Henslow, in which attention is drawn solely to those points of special importance.

It must also be borne in mind that the terms used are such as are in general use, and are to be taken in their conventional sense, and not as necessarily expressing the exact truth: thus, as has already been explained under the head of Morphology, when we say that one organ is *inserted into* another, it would be more correct to say that the one emerged from the other; in the same way many cases of so-called *cohesion* and *adhesion* are shown, by the study of the progressive development of the flower, to be rather cases of imperfect separation than of union of originally distinct organs.

In describing a plant fully, a commencement is made with the root, from which we proceed to the stem, leaves, inflorescence, flowers, and, finally, the ripe fruit and seeds.

In the case of the *root* the principal points to be looked to are:—first as to its *nature*, whether true or adventitious; then, in succession, its *form*, *direction*, *size*, degree and mode of *ramification*, *duration*, *consistence*, *surface*, *colour*, &c. Similar remarks apply to the *stem* and its modifications.

*Leaves* require first to be noted as to their *position*, radical, cauline, &c.; *insertion*, stalked or sessile; possession or deficiency of stipules; *arrangement*, alternate, opposite, &c.; *composition*, simple or compound; *direction*, *duration*, *texture*, *colour*, and *surface*. The *blade* of the *leaf* must then be described as to its *general form*, *outline*, *base*, *apex*, *margins*, *mode of venation*, *size* (especially in relation to the stalk, if present). The subdivisions of a compound leaf must be treated in the same manner as simple leaves. The *petiole* or leaf-stalk has to be noted as to its *form*, *surface*, *relative size*, &c. *Stipules*, as far as practicable, should be described in a similar manner to the leaves, as also should, *mutatis mutandis*, the *leaf-buds*. In their case, as also in the case of *flower-buds*, the mode of *vernation*, or of *æstivation*, as the case may be, should be ascertained and recorded. As regards the *inflorescence*, the principal things to be considered are its *position*, *direction*, *relative size* as compared with the leaf, *nature* (definite or indefinite), *ramification*, *form*, *number of flowers*, *duration*.

The *flower-stalks* follow the same rule as the leaf-stalks; but particular attention should be paid to the top of the flower-stalk (the *thalamus*) to see whether it be flat, convex, or concave. The *bracts* are described in the same manner as the leaves. In the case of the *calyx* and *corolla*, attention should be directed to their *construction* (cohesion), *relative position* (adhesion), *form*, *direction*, *colour*, *venation*, *surface*, *size*, absolute and relative, *duration*, *odour*, &c.

Individual *sepals* or *petals* should be described in the same way as the leaves.

*Stamens* should be described with reference to their *insertion* (adhesion), *cohesion* (free or united), *number*, *position*, *arrangement*, *size* (with reference to one another and to the other parts of the flower). *Filaments* present similar characters to those offered by the leaf-stalks, and are described accordingly. *Anthers* require attention as to their *form*, *mode of attachment* to the *filament*, *shape* and *number* of their *lobes*, their *mode of dehiscence*, *colour*, *surface*, the form and peculiarities of the *connective* and of any appendages that may be present. The *form*, *colour*, and distinctness or cohesion of the *pollen-grains* should, if possible, be stated. This is not always practicable unless recourse be had to the compound microscope, when other peculiarities, then visible, should be noted, as will be further explained in the section on Physiology.

After the stamens, the characteristics of the *disk*, if present, should be noted, and then those of the *pistil* as follows:—*number* of the constituent carpels, their *isolation* or *cohesion* and *arrangement*, their *adhesion* and *relative position*, *form*, *cavities*, *partitions*, and mode of *placentation*. The *styles* require to be noted with reference to their *position*, *number*, *size* (*relative* and *absolute*), *form*, *surface*, *colour*, &c. Similar remarks apply to the *stigma*. The *ovules* differ in their *position*, *mode of attachment*, *number*, *form*, &c. The *fruit* follows the same rules as the pistil; but, in addition, the *texture*, *mode of dehiscence*, and *number of seeds* must be noted.

*Seeds* are described much in the same way as ovules, taking care not to overlook any of the peculiarities presented by the *coverings* of the *seed* in the way of hairs, scales, arils, and the like: the interior of the seed also requires special attention, to see whether or not it be *albuminous* or *exalbuminous*; if the former, the nature and quantity of the *albumen* should be noted; and in any case, where possible, the *form*, *position*, *direction*, *size* of the *embryo* and its parts, the nature and number of the *cotyledons*, &c. should be accurately ascertained.

In the above remarks we have had in view a complete or nearly complete description. The student is recommended to take any plant he meets with, and endeavour to draw up a description of it with reference to the foregoing scheme. In this manner he will familiarize himself with the main points of difference between one plant or organ and another, and will learn to apply the appropriate *term* to each modification.

The subjoined description of the common white Dead-Nettle (*Lamium album*) is given as an illustration of a tolerably complete description of the external peculiarities of a plant; it may serve as a model to the student in drawing up similar descriptions. It is, however, advisable that he do not attempt too much at once. A bad or careless description is almost worse than none at all; hence the beginner is recommended to make himself pretty thoroughly acquainted with the peculiarities of such organs as are most easily studied before passing on to organs such as ovules &c., which require some considerable practice before their structure and characteristic features can be ascertained.

*Lamium album.*—A rather coarse hairy perennial, with a shortly creeping *stock*, from the joints of which, especially on the lower surface, proceed at intervals numerous slender, fibrous, brownish *roots*. *Stems* 1–2 feet high, herbaceous, decumbent or ascending, fistular, four-sided. *Leaves* exstipulate, opposite, stalked, the upper ones nearly sessile, membranous, *hairy*, *ovate*-acute or acuminate, cordate, coarsely and irregularly toothed, *unicostate*, *arch*-veined, 2–3 inches long, 1–2 inches broad. *Petiole* less than half the length of the blade, channelled on the upper surface, rounded beneath. *Flowers* pure white, sessile, in axillary cymose whorls (verticillasters) of 6–10 or more. *Calyx* campanulate, of 5 sepals, united below into a *tube* traversed by 10 ribs; *limb* divided above into five nearly equal, spreading, linear, ciliated segments, of which the uppermost stands slightly apart from the others. *Corolla* white, tubular, bilabiate, twice the length of the calyx; *tube* curved, ventricose, as long as or longer than the calyx, scabrous inside, with a ring of hairs near the base; upper lip erect, concave, notched, hairy on the outer surface; lower lip spreading, 3-lobed, the middle lobe broad and 2-lobed, the two lateral ones smaller and pointed. *Stamens* 4, didynamous, epipetalous; *filaments* downy, springing from the upper part of the tube of the corolla, partially concealed within the upper lip. *Anthers* innate, 2-lobed; lobes superposed, oblong, blackish, introrse, dehiscing longitudinally; *connective* covered with white hairs. *Pollen* yellowish white. *Ovary* small, truncate, 4-lobed, 4-celled, encircled at the base by a pale green, cup-like disk. *Ovules* solitary in each cell, anatropal. *Style* single, basilar, thread-like, as long as the corolla, terminating in a 2-lobed stigma; lobes of the stigma short, oblong, pointed. *Fruit* of four, or fewer by abortion, 1-celled, 1-seeded, indehiscent, blackish shining lobes or achenes. *Seeds* solitary, erect, inverted, exalbuminous. *Embryo* straight; *cotyledons* large, plano-convex; *radicle* short, inferior.

328. Such descriptions are now usually given in a modern language when occurring in works descriptive of the plants of particular countries &c. In general systematic works, or in isolated notices, published in periodicals or Transactions, the Latin language is usually preferred.

329. Detailed descriptions are commonly given only where new species are established, or when an uncertain nomenclature is to be made clear and definite, in a monographic or a general systematic work. The classification of plants into genera, families, &c., in the Natural System, renders the repetition of the peculiar marks of these groups unnecessary in the characterization of the subordinate groups or forms. For this reason, *characters* and *diagnoses* commonly replace the complete descriptions of species in ordinary descriptive botanical works, since, as the character of the genus includes those peculiarities of the floral organs which are common to all its species, and which constitute the bases of the genus, it is only requisite to connect with each species the character by which the species are distinguished from each other.

The following condensed description of the white Dead-Nettle, from Bentham's 'Handbook of the British Flora,' will show how, when the characters of the order and genus are known, a faithful portrait of the species, and one comprising the most conspicuous features only, may be drawn up. "A rather coarse hairy perennial, with a shortly creeping stock, and decumbent or ascending branching stems, seldom above a foot high. Leaves stalked, coarsely crenate. Flowers pure white, in close axillary whorls of 6–10 or more. Calyx-teeth fine, long, and spreading. Tube of the corolla curved upwards, and longer than the calyx, with an oblique contraction near the base, corresponding with a ring of hairs inside; the upper lip long and arched; the lateral lobes of the lower one slightly prominent, with a long fine tooth." Then follows an account of the *station* in which the plant is found, and of its geographical distribution throughout this country and the continent.

330. Having gained a general idea of what points are to be looked to in drawing up a description of a plant, and having acquired a familiarity with the meaning and application of terms, it is particularly desirable that the student should be able to form an estimate of the *relative value* and *importance* of characters for practical purposes; for instance, those characters which serve to identify and distinguish large groups of plants are of more consequence than such peculiarities as pertain merely to small groups, or to individual plants. With a view to fix the attention on the more important or cardinal characters, those which are of most use in drawing up a *diagnosis* of a plant or of a group of plants, a form of schedule is given; and the pupil is recommended to make similar ones for himself, and by their aid to draw up an account of the more important characters of any flowers he meets with, checking them and comparing them with the descriptions given in books, or with the instructions of his tutor. These schedules should be kept for comparison with others relating to other plants: and by this method a practical insight into plant-construction, and the relationships of one plant to another, may be more speedily and thoroughly obtained than by any other means. The schedules here inserted by way of illustration are filled up from a Common Buttercup (*Ranunculus*), and from a Dead-Nettle (*Lamium*). The characters therein given are sufficient to enable the student to determine the *orders* to which the plants belong, which is the first and most important consideration, but they are not sufficient to indicate the *genus*, still less the particular species. To discriminate these minor groups, recourse must be had to the other peculiarities presented by the plants in question, as before detailed.

***Ranunculus* (Buttercup).**

| Organ. | Number. | Isolation. | Insertion. | Cohesion. | Adhesion. | Symmetry. |
|---|---|---|---|---|---|---|
| Calyx | polysepalous | ............... | ............... | ............ | ............ | regular. |
| Sepals | 5 | distinct | hypogynous. | | | |
| Corolla | polypetalous | ............... | ............... | ............ | ............ | regular. |
| Petals | 5 | distinct | hypogynous. | | | |
| Stamens | polyandrous. | | | | | |
| Filaments | ............... | distinct | hypogynous | ............ | ............ | regular. |
| Anthers. | | | | | | |
| Pistil | polycarpous. | | | | | |
| Carpels | ............... | distinct, apocarpous. | ............... | ............ | ............ | regular. |

***Lamium* (Dead-Nettle).**

| Organ. | Number. | Isolation. | Insertion or Emergence. | Cohesion. | Adhesion. | Symmetry. |
|---|---|---|---|---|---|---|
| Calyx | ............... | ............... | ............... | gamosepalous | ............ | irregular, bilabiate. |
| Sepals | 5 | ............... | hypogynous. | | | |
| Corolla | ............... | ............... | ............... | gamopetalous | ............ | irregular, bilabiate. |
| Petals | 5 | ............... | hypogynous. | | | |
| Stamens. | | | | | | |
| Filaments | 4 | distinct | perigynous | ............ | epipetalous | irregular, didynamous. |
| Anthers. | | | | | | |
| Pistil. | | | | | | |
| Carpels | 2 | ............... | ............... | syncarpous | ............ | irregular. |
| Ovary | 4-lobed. | | | | | |
| Styles | 2 | ............... | ............... | confluent | ............ | basilar. |
| Stigmas | 2 | distinct. | | | | |

331. The *generic character* is perhaps the most important element in Systematic Botany. It should contain a short description of the peculiarities of the group, so as at once to characterize this as it exists in itself, and to furnish the means by which it may be distinguished from all other genera belonging to the same division of the Vegetable Kingdom. That is to say, for a genus of Flowering Plants, the character should contain all that is necessary to distinguish a given genus from all other genera of Dicotyledons, or of Monocotyledons, as the case may be. The following example of the character of the genus *Campanula*, Linn., as given in Endlicher's 'Genera Plantarum,' will illustrate this:—

"*Campanula*, Linn. *Calyx* with an ovoid or subspherical tube adherent to the ovary, the limb superior, five-toothed; the teeth either flat at their margins or decurrent into lobes overlying the sinuses. *Corolla* inserted at the summit of the tube of the calyx, more or less campanulate, five-lobed or five-toothed at the apex. *Stamens* five, inserted with the corolla; filaments broadly membranaceous at the base, and, with the anthers, free. *Ovary* inferior, three- or five-celled; cells opposite the lobes of the calyx. *Ovules* numerous, on placentas projecting from the central angles of the cell, anatropous. *Style* covered with quickly deciduous hairs; *stigmas* 3–5, filiform. *Capsule* ovate or turbinate, 3–5-celled; cells bursting near the top or bottom by a parietal valve turning upward. *Seeds* numerous, mostly ovate, flattened, more rarely ovoid and very small. *Embryo* orthotropous, in the axis of fleshy albumen; *cotyledons* very short; *radicle* next the hilum, centripetal.

"Perennial or annual herbs, sometimes low and tufted, sometimes erect, tall, many-flowered, diffused through all the temperate and cool regions of the northern hemisphere, forming a great ornament to meadows and groves; radical leaves very often larger and more obtuse, with longer stalks; stem-leaves alternate, varying; flowers mostly stalked, racemose, rarely spiked or in clusters, very often rather large, blue, or sometimes white in the same species."

332. The first paragraph here contains the *essential character* of the genus; the second paragraph is a description of the general characters of the species belonging to it, which is usually appended to such complete generic characters.

It will be observed that this generic character not only enables us to distinguish plants belonging to this group, but describes the genus so fully that we become acquainted with all its important peculiarities, while, being drawn up irrespectively of any Order, alliance, or class, it is equally available as material for any Natural or Artificial classification of Flowering plants founded on the floral organs, since it contains the information requisite for ascertaining its relations.

333. The *diagnosis* of a genus is more limited in its nature and purpose. It is used, when genera are described under fixed systematic heads, simply for distinctive purposes; and it is therefore confined to denoting what is absolutely necessary for this pur-

pose. Thus, in Babington's 'Manual of British Botany,' the genus *Campanula* occurs under the head of the Order Campanulaceæ, the character of which includes much of what is given in the generic character of *Campanula*, above cited; so that it suffices for the distinction of *Campanula* from its allied genera to give the following brief abstract, or *diagnosis*:—

"*Campanula*. *Calyx* 5-parted. *Cor.* mostly bell-shaped, *with 5 broad* and shallow segments. *Anthers* free; *filaments* dilated at the base. *Stigma* 3–5-fid. *Capsule* not elongated, 3–5-celled, opening by lateral pores outside the segments of the calyx."

334. It is seen at once that this *diagnosis* fails to furnish the complete notion of the genus which is obtained from the *character*, and that it does not suffice to indicate the position of the genus, either in a Natural or Artificial classification. On the other hand, for its own especial purpose, that is, of indicating the distinctions between allied genera, it may be even still more reduced, as is often done in works describing the plants of a limited district, where only a few genera occur in the Natural Order; for example, we might give diagnoses of the British genera of Campanulaceæ in this way—

A. Corolla rotate, segments linear; anthers cohering at the base. 1. *Jasione*.
  Corolla rotate, with linear segments; anthers free. 2. *Phyteuma*.
B. Corolla mostly bell-shaped, with broad and shallow segments; anthers free.
    Capsule not elongated, opening by lateral pores outside the segments of the calyx .................... 3. *Campanula*.
    Capsule linear-oblong, prismatic, opening by lateral pores between the segments of the calyx ........ 4. *Specularia*.
    Capsule half-superior, opening by 3–5 valves within the segments of the calyx .................... 5. *Wahlenbergia*.

335. The *specific character* of a plant should contain all the constant distinctive peculiarities of a species. On the one hand, it will exclude the generic characters which ally it to other species of the same genus; on the other, it should exclude the inconstant characters which distinguish its own varieties. But the character of its ordinary varieties, if such exist, may be given in a supplementary paragraph, like that appended to the full generic character. The distinctive characters of species are usually found in the organs of vegetation, as the root, stem, leaves, bracts, and inflorescence, or in the habit or duration of the plant. The floral organs mostly only give specific characters in their less important peculiarities—as in the shape and relative magnitude of the petals, the external characters of the fruits and seeds, &c.,—the more remarkable peculiarities being of generic value. The supplementary notices appended to the strict character of the species generally relate to the ordinary dimensions of

the plant, the colour, taste, smell, &c. of its organs; these are the marks by which the *varieties* are usually characterized, as will be seen by referring to any catalogue of varieties of the ordinary cultivated vegetables.

336. Linnæus laid down a rule, that every specific character should be confined to twelve words; but, from the increased number of species discovered since he lived, it is no longer possible to follow this rule in all cases. In recent systematic works the characters of species have often been given at inordinate length, and in a manner greatly transgressing the other more important rule, that they should contain no character that is not to be found in all perfect specimens of the plant. The specific character will necessarily vary in length according to the richness of a genus in species, some containing many hundreds, while others comprise but a single one. When the genus contains but a single species, as the Hop (*Humulus Lupulus*), the generic character alone suffices for distinguishing it; but a specific character is even then given with advantage, indicating points which are not included in the strict generic character. Where a large number of species exist, the genus is generally broken up into artificial sections, characterized by some mark occurring regularly in a certain number, which are thus placed under one head: this saves the necessity of repeating that character for each species. It is also common in modern works to combine a diagnosis with the specific character, by marking in italics the especial distinctive marks of each species occurring in a particular group.

The following examples will make this more clear:—

Of *Syringa*, L., only six species are described in De Candolle's 'Prodromus,' being all that were known in 1844. The specific character of the common Lilac, *Syringa vulgaris*, could thus be given in a few words:—

"*S. vulgaris*, L. Leaves cordate or ovato-cordate, quite smooth and of even colour; limb of the corolla subconcave."

Four varieties are characterized, chiefly distinguished by the colours of the blossoms.

Turning to the genus *Campanula* in the same work, we find no less than 182 species. Being a very natural genus, the species are kept together under one generic name, but, for convenience, they are arranged in sections and subsections. Thus fifty-eight of them are characterized by the presence of appendages on the sinuses of the calyx, such as we find in the garden Canterbury Bell (*Campanula Medium*), while the remainder are without these. The second section, of 124 species (among which are included all our native kinds), is further divided into subsections, characterized principally by the peculiarities of the *capsule*, and these, again, into groups according to the kind of *inflorescence* &c.; so that when we come to the specific character itself none of these points have to be repeated, and the definitions are restricted within very narrow limits, as for instance:—

"*C. rotundifolia*, L. Radical leaves stalked, cordate, rounded, crenatodentate; stem-leaves linear or lanceolate; teeth of the calyx awl-shaped, erect, one-third the length of the bell-shaped corolla."

In a work devoted to a limited flora, as that of Britain, where there exist only eight species of *Campanula*, we may adopt the sectional divisions, and limit the specific character as above, or give a longer character, including the marks of the sections; the latter plan is the better, where space is not an object, since it makes the character itself more instructive, Thus, in the 'British Flora,' we find—

"*C. rotundifolia*, L. Glabrous; root-leaves subrotundo-cordate, crenate (very soon withering), lower cauline ones lanceolate, upper linear entire; flowers solitary or racemose, drooping; calyx-segments subulate; capsule drooping, with the clefts at the base."

In Babington's 'Manual,' on the contrary, where the subsections founded on the capsule are adopted, this mark is omitted in the essential character:—

"*C. rotundifolia*, L. *Radical leaves cordate or reniform*, shorter than their stalks; *stem-leaves linear*, the lower ones lanceolate; *flowers one or more*, racemose; corolla turbinate-campanulate.—Stem 6–12 inches high. Radical leaves soon vanishing; corolla blue; calyx-segments linear-subulate."

This example further illustrates the method of giving a *diagnosis* at the same time, by *italicizing* the characters by which the species is distinguished from its nearest allies; it also shows the manner in which explanatory or descriptive notices are added in a supplementary paragraph to the essential specific character.

337. Lastly, if we have to deal with a limited number of species, such as the British Bell-flowers, to which we have just referred, we may, for simple purposes of distinction, construct a diagnostic table, like that above given for the genera of Campanulaceæ.

| | |
|---|---|
| Flowers sessile, in terminal or axillary clusters; capsule sessile, erect, with the pores at the base . . | *C. glomerata.* |
| Flowers in racemes or panicles; capsule stalked. | |
| Capsule nodding, with the pores at the base. | |
| Flowers in a unilateral raceme, segments of calyx ultimately reflexed . . . . . . . | *C. rapunculoides.* |
| Flowers racemose, segments of calyx always erect. | |
| Peduncles 1-flowered . . . . . . . . | *C. latifolia.* |
| Peduncles 2–3-flowered . . . . . . . | *C. Trachelium.* |
| Flowers on long slender stalks, solitary, or in a lax few-flowered corymbose raceme . . | *C. rotundifolia.* |
| Capsule erect, with the pores just below the segments of the calyx. | |
| Segments of the calyx entire. | |
| Segments of the calyx lanceolate, raceme few-flowered, or flower solitary . . . | *C. persicifolia.* |
| Segments of the calyx awl-shaped, flowers in an erect racemose panicle . . . . | *C. Rapunculus.* |
| Segments of the calyx toothed at the base; flowers panicled, erect, on long stalks . | *C. patula.* |

338. A few of the general rules observed in writing descriptions of plants may be mentioned here, as explanatory of certain technicalities which will be met with in systematic works.

339. The generic name is always commenced with a capital letter, while that of the species is usually written small; but we find in most books a capital letter to the specific name, 1, where this name is the appellation of another existing or suppressed genus used adjectively, as *Agrimonia Eupatorium*, *Mentha Pulegium*, &c.; 2, where the specific name is formed from a proper name, either as the genitive case of a substantive or in the adjective form, as in *Scirpus Savii* and *Carex Davalliana*. Specific names derived from countries are now usually written small, as *Silene anglica*.

340. When a generic character is written in Latin, the organs are all put in the nominative case; in a specific character they are put in the ablative.

341. When describing a species, it is usual to subjoin its habitation (*Habitat*)—that is, the nature of the places in which it is usually found, such as "Woods," "Dry hilly places," "Rivers," &c. In general systematic works the native country or province is stated; in works relating to limited districts, special *localities* are given for rare plants.

342. The following marks and abbreviations are commonly in use to indicate certain other points:—

① or A = an annual plant.
② or B = a biennial.
♃ or P = a perennial.
Sh = a shrub.
T = a tree.

♂, a male flower.
♀, a female flower.
⚥, an hermaphrodite flower.
♂ ♀, a monœcious plant.
♂–♀, a diœcious plant.

The time of flowering is indicated by numbers, referring to the months, as 6–8 or vi–viii = June to August, &c.

Many other signs are met with in Systematic works, but they are very often used in different senses by different authors, so that no general explanation of them can be given; moreover the sense in which they are used is generally explained by the author.

# CHAPTER II.

## SYSTEMS OF CLASSIFICATION.

### Sect. 1. Artificial Classification of Plants.

343. An arrangement of all known species of plants in a series of classes constituted upon certain fixed principles, forms what is termed a System of Vegetables.

It belongs to the history of Botany to describe the numerous Systems which have been brought forward, at various periods, for the double purpose of generalizing acquired facts, and of facilitating the diffusion of botanical knowledge by rendering it possible to recognize plants which have already been described. In this work it is necessary to confine ourselves to a brief reference to some of the most important of the Systems which have attained general currency.

344. The classification of plants by generalization, the Synthetic or Natural Method, is adopted in all cases in forming the groups of the lowest rank, namely *Genera*. These are established by the combination of a number of allied species under one name, on account of their affinities; and, as we have already mentioned (§ 332), the same genera are used in all Classifications.

From this point Systems diverge. The *Natural Method* is pursued further on the same principles of generalization, where the object is to systematize acquired knowledge, and mark the agreements among plants. Where, on the other hand, it is chiefly desired to mark out the differences of plants, in order simply to their easy recognition, *Artificial Methods* are resorted to, which are carried out by a principle of *analysis*, whereby the whole mass of known forms are taken and gradually parcelled out into Classes, Orders, &c., according to their agreement or difference in certain fixed characters.

Most of the older systems were more or less Artificial, the earliest commencing with the division of plants into Trees, Shrubs and Herbs, Land-plants and Water-plants, and the like. As advances were made, organs of more and more importance were chosen to furnish characters; and we find plants subsequently classed by their *corollas*, by their *fruits*, &c.; but in none of the systems proposed before the time of Linnæus do we find one given principle carried out through the whole.

345. When Linnæus entered upon his wonderful labours, there lay before him a mass of information in a very crude and unmanageable condition. His reforming genius introduced order, in the first instance, by the substitution of short fixed names for species, on the binomial plan, by the definition and secure establishment of imperfectly cha-

racterized genera and species, and then advanced to the necessary task of arranging the genera so as to render them recognizable. The artificial methods founded on the floral envelopes &c. had proved inefficient; and therefore he turned to the *essential organs* of flowers, the physiological importance of which he himself contributed greatly to establish. The selection of these organs resulted in the formation of an Artificial System in which a fixed principle is regularly carried out, and which, from the physiological importance of the characters employed, approaches in certain of its coordinations to a natural arrangement.

Until the establishment of a true principle for natural Classification, the materials for which accumulated rapidly under the influence of the Linnæan System, the latter received almost universal acceptance; and it is still retained by botanists as a valuable key to the recognition of genera, especially by beginners in the science. On account of its own importance, therefore, and as the best example of the Artificial Method, a brief explanation of it must be given in this work.

346. *Species* and *Genera* (§§ 308–313) form the foundation of all Systems. The object of the Linnæan System was to arrange genera in groups characterized by simple striking marks, so that the existing description of a given plant might be readily found, or the description of a new plant might be placed where it would be easily referred to. Such marks Linnæus obtained in the *essential* or *sexual organs* of plants (in flowers, the *stamens* and *pistils*), whence his System is sometimes called the Sexual System. The highest or most general groups, which he called *Classes*, are founded on the conditions of the *stamens*. These Classes are subdivided into *Orders*, founded either on the conditions of the *pistils* or upon *secondary characters of the stamens*. The Orders include the *Genera* (in large Orders grouped into sections according to various artificial characters).

The Linnæan Classes are twenty-four in number, of which the first twenty-three include all Flowering Plants: the twenty-fourth, Cryptogamia, including all Flowerless Plants, was a *chaos* when first established, and its subdivisions were not then definable by single characters.

The following Tables exhibit the main features of the Linnæan Classification. The technical meaning of the names applied to the Classes has been explained already in the First Book, in the sections on the Morphology of the essential organs. The few technical names of Orders requiring special explanation are noticed below.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Plants with evident stamens and pistils. | Stamens and pistils in the same flower. | Stamens not adherent to the pistils. | Stamens distinct from each other. | Stamens equal in length when more than 3 in number. | 1 Stamen | | 1. Monandria. |
| | | | | | 2 Stamens | | 2. Diandria. |
| | | | | | 3 „ | | 3. Triandria. |
| | | | | | 4 „ | | 4. Tetrandria. |
| | | | | | 5 „ | | 5. Pentandria. |
| | | | | | 6 „ | | 6. Hexandria. |
| | | | | | 7 „ | | 7. Heptandria. |
| | | | | | 8 „ | | 8. Octandria. |
| | | | | | 9 „ | | 9. Enneandria. |
| | | | | | 10 „ | | 10. Decandria. |
| | | | | | 12 to 19 | | 11. Dodecandria. |
| | | | | | 20 or more | Inserted on the calyx | 12. Icosandria. |
| | | | | | | Do. on the receptacle | 13. Polyandria. |
| | | | | Stamens 4 or 6, unequal in length. | Stamens 4, 2 long and 2 short | | 14. Didynamia. |
| | | | | | Stamens 6, 4 long and 2 short | | 15. Tetradynamia. |
| | | | Stamens coherent. | By the filaments. | Into 1 parcel | | 16. Monadelphia. |
| | | | | | „ 2 parcels | | 17. Diadelphia. |
| | | | | | „ 3 or more parcels | | 18. Polyadelphia. |
| | | | | By the anthers | | | 19. Syngenesia. |
| | | Stamens adherent to the pistil | | | | | 20. Gynandria. |
| | Stamens and pistils in distinct flowers | On the same plant | | | | | 21. Monœcia. |
| | | On distinct individuals | | | | | 22. Diœcia. |
| | | Perfect flowers occurring with staminate or pistillate flowers or with both | | | | | 23. Polygamia. |
| Plants without evident stamens and pistils | | | | | | | 24. Cryptogamia. |

Those Syngenesious plants which have solitary flowers, such as *Lobelia*, *Viola*, &c., are placed in the Order to which the number of stamens refers them (here Pentandria); so that the Class 19 corresponds exactly to the Natural Family of Compositæ.

## THE LINNÆAN ORDERS.

| | | |
|---|---|---|
| Classes I. to XIII.<br>The Orders formed according to the number:—1, of pistils when these are distinct; or, 2, of styles of compound pistils; or, 3, of the stigmas when no styles exist. | 1 pistil | 1. Monogynia. |
| | 2 pistils | 2. Digynia. |
| | 3 " | 3. Trigynia. |
| | 4 " | 4. Tetragynia. |
| | 5 " | 5. Pentagynia. |
| | 6 " | 6. Hexagynia. |
| | 7 " | 7. Heptagynia. |
| | 8 " | 8. Octogynia. |
| | 9 " | 9. Enneagynia. |
| | 10 " | 10. Decagynia. |
| | 11–12" | 11. Dodecagynia. |
| | More than 12 | 12. Polygynia. |

The termination *-gynia* is here used to express pistils &c., as *-andria* is to express stamens in the Classes. The Orders above given do not exist in all the Classes, mostly only the first two, together with one or other of the rest, in which case the ordinal number is modified; for instance, if no Trigynia or Tetragynia exist, and Pentagynia does, this will follow Digynia, and become the 3rd Order.

| | | | |
|---|---|---|---|
| Classes XIV. & XV.<br>The Orders formed from the condition of the fruits. | Didynamia. | Naked-seeded | 1. Gymnospermia. |
| | | Covered-seeded | 2. Angiospermia. |
| | Tetradynamia. | With silicules | 3. Siliculosæ. |
| | | With siliques | 4. Siliquosæ. |

The term Gymnospermia, used in the 14th Class, was founded on an erroneous idea of the fruit of *Labiatæ*, *Boraginaceæ*, and other families, which consists of a *carcerulus* (§ 270) of four hard achænia, regarded by Linnæus as naked seeds; while the Angiospermia included the plants with a capsular fruit. The terms *Silicula* and *Siliqua* are explained in the descriptions of fruits (§§ 274, 275).

| | | |
|---|---|---|
| Classes XVI., XVII. & XVIII.<br>The Orders founded on the number and position of the stamens, like Classes I. to XIII. | 5 free stamens | 1. Pentandria. |
| | 6 " | 2. Hexandria. |
| | 7 " | 3. Heptandria. |
| | 8 " | 4. Octandria. |
| | 10 " | 5. Decandria. |
| | 12–19 " | 6. Dodecandria. |
| | 20 or more stamens on the calyx. | 7. Icosandria. |
| | 20 or more stamens on the receptacle. | 8. Polyandria. |

| | | |
|---|---|---|
| Class XIX.<br>Orders formed according to the sex of the florets contained in the same capitulum. | All the florets perfect and of the same shape. | 1. Polygamia æqualis. |
| | Capitules radiate; disk-florets perfect, ray-florets pistillate, all forming seed. | 2. Polygamia superflua. |
| | Like the last, except that the ray-florets are barren. | 3. Polygamia frustranea. |
| | Ray-florets fertile, disk-florets barren. | 4. Polygamia necessaria. |
| | Ray-florets perfect, each floret with an additional "calyx" or involucel. | 5. Polygamia segregata. |
| Classes XX., XXI., XXII. & XXIII. | The Orders formed according to the number and position of the stamens, like the Classes I.–XIII., or according to their cohesion, like the Classes XVI.–XIX. | Names of the Orders the same as those of the Classes they imitate. |

The number of actually existing Orders is limited here to far less than all the *possible* cases.

| | | |
|---|---|---|
| Class XX. | Divided according to Natural relationships into ........ | 1. Filices.<br>2. Musci.<br>3. Algæ.<br>4. Fungi. |

347. The completeness of this Artificial System is such, that almost every form of plant can be readily referred to a place in it. Unfortunately, however, this is done in certain cases at the expense of natural affinities so close as those between the species of the same genus; while in some instances it divides the individual examples of the same species. As it is contrary to the object of the System to interfere with generic groups, far less with the definitions of species, a choice has to be made in such cases as to where the forms in question shall stand—the character of the majority of the species deciding the place of a genus, and the character of the majority of examples that of a species. Moreover some of the Classes are so natural as regards the affinities of the constituent genera, that where, as sometimes happens, exceptional genera exhibit a deviation from the artificial type, a kind of compromise is made and the genus described with its true allies, a reference being made to it under the artificial Class to which it strictly belongs.

A few examples will illustrate these points, which render the use of the Linnæan System more difficult to beginners than is generally admitted.

The garden Rue (*Ruta graveolens*) has sometimes quaternary flowers with 8 stamens, sometimes quinary flowers with 10 stamens. It is described by Linnæus in the Class Decandria; but it is necessary to include it in the table of genera of Octandria also, with a reference to the place where the description is given.

In the genus *Festuca*, the species are usually *triandrous*; but *F. uniglumis* and others have but one stamen: consequently while the genus stands under Triandria in the System, a reference must be made to it under Monandria. *Lepidium* and *Cardamine* are genera of Tetradynamia, a Class of such closely associated genera that it corresponds to the Cruciferæ of Natural Systems; but *L. ruderale* is only known in a *diandrous* state, and specimens of *C. hirsuta* are not unfrequently found *tetrandrous*, which cases demand similar cross-references in the tables of genera.

The Classes founded on the *diclinous* conditions of plants are the least satisfactory of all. It is exceedingly common to find species with *perfect* flowers and other species with *monœcious* or *diœcious* flowers, in the same genus, as *Lychnis dioica* (in the 10th Class), *Valeriana dioica* (in the 3rd Class), *Ribes alpinum* (in the 5th Class), &c., in genera where the species mostly possess perfect flowers. *Rhamnus cathartica*, *diœcious* and *tetrandrous*, and *R. Frangula*, *perfect* and *pentandrous*, represent that genus in the British Flora; while *Urtica dioica* and *U. urens* furnish examples of congeneric species respectively *diœcious* and *monœcious*. All such cases require the same kind of cross-reference as above indicated.

The characters of the 23rd Class, Polygamia, are subject to the great inconvenience that they frequently require the examination of a large number of specimens in order to make them out clearly. On this account many authors have discarded this Class, and distributed its genera among the others.

The arrangement of the genera in Orders is accompanied by similar difficulties, which are met by the same rules, that the place shall be decided by the greatest frequency of occurrence of a character in a species or genus, and that a cross-reference shall be made.

348. In almost all modern descriptive works, the species are described under a Natural Arrangement; and the Linnæan System is seldom had recourse to, except as a means of furnishing an Artificial Key to the genera of a limited region. It has certain advantages for this purpose, arising from the difficulty of subdividing the Natural Families into sections which are not too few or too numerous, in making the first step of the analysis. By the Linnæan plan, the Flowering plants of Britain, for instance, comprised in about 500 genera, are at the outset distributed into 22 well-marked Classes, each of which is again divisible into from 2 to 7 Orders, after which the detection of the genus is generally very easy.

## Sect. 2. NATURAL CLASSIFICATION OF PLANTS.

349. We have pointed out, in a former section, that the *genera* of plants are truly natural groups; and, if their essential characteristics are clearly understood, there will be no difficulty in comprehending the scope and purpose of the Natural System of Plants. In this method of classifying we pursue the same path by which we arrived at the genera, and proceed to combine these into higher and more general groups, not according to arbitrarily chosen or isolated cha-

racters, but according to their natural affinities—that is, the agreement in their total organization. Genera are thus gathered together into *Families* or *Orders*, these into *Classes* of higher generality, and finally the entire Vegetable Kingdom becomes marshalled into a few *Provinces* or *Subkingdoms*.

It is evident from this, that a Natural System founded on a perfect knowledge of all existing plants would present to us a kind of abstract picture of the Vegetable Kingdom, in which all its essential characters would be represented in their real proportions, places, and connexion. Not only, however, are we far from being acquainted with all existing plants (not to mention the numerous kinds now extinct), but the essential peculiarities of a vast number of the known plants have been as yet but imperfectly studied. Hence we have at present various forms or plans for the Natural Arrangement of plants, presenting peculiarities dependent upon the amount of knowledge, or the peculiar views, of their respective authors; which plans or Systems must be regarded as so many rough draughts or sketches, to serve as material for the elaboration of the true and complete Natural System. As the principles of classification are fully recognized, and as the amount of plants thoroughly known is already very large, there is a close agreement in the general features of the different "Natural Systems," and especially in the manner in which the Orders of plants are defined. The chief diversities of opinion arise out of the different estimations of affinities and differences of the families, which express themselves in a marked manner in the mode in which the Classes or Alliances are formed. This will be evident in the examples we shall presently give of those "Systems" which have received the widest acceptance.

350. We have said above, that plants are combined according to the agreement in their total organization. But, to characterize the Natural Method more distinctly, it must be added that especial attention is paid to the estimation of the relative value of the different characters presented by each plant, a determinate scale being formed, in which the organs are ranked according to their physiological importance, the morphological complexity of their construction, and their comparative invariability.

Thus, while species of the same genus, distinguished generally by the external characters of their vegetative organs, are combined by likeness in their flowers, genera (in which difference of the floral envelopes, or of the external character of the fruit, or some such character exists) are combined into an Order on account of the agreement in the structure of the ovary and its relations to the floral envelopes. The characters of seeds, and more particularly of the embryos, give a still higher divisional character. These characters of successively higher groups are marked in organs of progressively higher physiological and morphological importance, affinities between such organs being proportionately more valuable. But they possess this value not merely on their own account; for if that were the case, the method would be still to a great extent artificial: they indicate the coexistence of proportionate agreement in the total organization, which renders them exponents not merely of the affinities of the plants in respect to the particular structure to which they belong, but of all their affinities, and of the rank which a given plant holds in the Vegetable Kingdom. As a general rule, it is found that the agreement of the total organization of plants is generally proportionate to the physiological value of any given organs in which they agree; or, in other words, agreement in the structure of any given organ indicates general agreement in all the organs of less importance than itself. The agreement here referred to is of course a general structural agreement, a relation to a common type—not a resemblance excluding the multifold minor diversities which present themselves within the limits of almost every type.

351. Practically, moreover, we have another principle to keep in view, which indeed, while it affords as it were the verification of the inductions of the above principle, is our sole guide in dealing with the subdivisions of the more comprehensive types. This is the rule that the closest affinities are marked by the agreement in the majority of characters of *equal* importance; or if the characters, as is more commonly the case, are of unequal importance, the principle of decision by the majority is carried out by ascertaining the proportionate values of the organs in which agreements and differences exist, and striking a balance as with equal factors.

Many of the older botanists had attempted to construct a Natural System; and Linnæus left a sketch or fragment of one, in the form of a list of names of families without definitions, regarding its realization as the ultimate aim of Botany. Many of the families in these older Systems are grounded almost exclusively on "habit," or general external character. The two Jussieus, Bernard and Antoine-Laurent, have the merit of the discovery of the only principles upon which a really Natural System can be founded. And so accurately did A.-L. de Jussieu carry out these principles in his arrangement of the then existing genera, that the families which he established are still almost all received into our present Systems, where some of them are indeed broken up into smaller groups, but where the greatest increase in the number of families arises from subsequent discoveries.

352. The families of Jussieu consisted of groups of genera combined together upon the principles above enunciated. He established 100 of them, defining them with exactness, and assigning to their characters relative values, primary, secondary, tertiary, &c., and in this way he laid the foundation of the classifications now in general use.

The characters of the natural Families established in this way will be found to be far less exact and definite than those of the Linnæan classes and orders, and by no means so rigid even as those of natural genera. The character of a family is founded on the *totality* of its essential characters, and includes the essential characters of agreement of all its genera. The genera contained in most of the families exhibit a considerable range of differences; allowance must be made for these; and this gives a laxity to the family character which is puzzling to the beginner. For example, the family Ranunculaceæ is very natural; but we find in its character a certain range of difference allowed for in the sepals, petals, pistils, and fruit; the insertion of all these, however, and that of the stamens, is fixed, and so is the character of the seed. Similar conditions occur in most other families. The decision as to what family a genus is to be referred to is made according to the principle of majorities: whichever it agrees with in *most* of its characters (say, even three out of five), to that family it belongs. Great difficulty, however, exists in certain cases from a vast series of genera running into one another by almost imperceptible gradations, and this in different directions. A considerable number of these agreeing closely are associated into a family; another similar group form another family, and so on; and then, in the course of time, sundry intermediate genera present themselves, which connect the established families, and which it is difficult to place by the usual choice in either one or the other, the characters being balanced. Thus the Natural family Loganiaceæ is connected by "aberrant" genera with Rubiaceæ, Gentianaceæ, Scrophulariaceæ, and other families which are truly natural, but which in this way come to be separated by somewhat indefinite boundary-lines.

The fact is, that the Vegetable Kingdom is a whole, the families and classes having seldom a distinct isolated existence, except in the minds of botanists; and we must regard them as analogous to countries on the globe, which are parcelled out under distinct names, but most often adjoin and run into one another, being only separated by an arbitrary boundary-line or frontier. Some, indeed, lie off from the rest, like islands; but these are the exceptions.

Such exceptions are found among the families which were perceived and established by the older botanists, in which the essential agreements are accompanied by a striking character of external habit, as in the Grasses, the Umbelliferæ, the Compositæ, the Leguminosæ, the Coniferæ, the Palms, &c. Such remarkable peculiarities as these families possess, mostly prevent them being broken up into smaller groups, as has occurred to many of the earlier orders of large extent; and most botanists prefer to distribute these genera into *suborders* rather than discard the characteristic general name. Examples of these are found especially in the Leguminosæ, Rosaceæ, and Compositæ.

353. The Families or Orders are for the most part the same, in all essential respects, in all existing "Natural Systems." A considerable diversity presents itself in the modes in which different authors have grouped these into *Classes* or *Alliances*, as will be seen even by comparison of the Tables of Endlicher and Lindley, given below. These, however, are still Natural groups, as are also those of still higher generality indicated in the chapter on General Morphology (§ 17). But all writers on Systematic Botany have found it requisite to group the Orders or Classes of Flowering Plants into sections of somewhat less generality than Dicotyledons and Monocotyledons, as these re-

spectively include series of families so extensive as to be inconvenient in practice if left undivided. The members of these series, however, are so intimately connected together by their natural affinities, that it has been found indispensable to have recourse to certain arbitrary or artificial characters for the foundation of the sections—characters derived chiefly from the conditions of the petals and stamens. The nature of these Sections will be best understood from the examples which follow.

354. Jussieu established his primary divisions of the Vegetable Kingdom on characters which, although not altogether unexceptionable, define really natural groups, which are found under different titles in all Natural Systems. The characters were the absence or presence of the rudimentary plant or embryo, and its structure when present, in the seed. On these characters stood the three divisions *Acotyledons* (plants without an embryo), *Monocotyledons*, and *Dicotyledons*. The first of these names is bad, as founded upon a *negative* character; but the plants which it included were imperfectly understood in the time of Jussieu; the Acotyledons correspond to the Cryptogamia of Linnæus, which are now by more complete analysis distributed into two sections, divided by even more important characters than the Monocotyledons and Dicotyledons. The other two divisions are still retained, with very slight modification, in all Systems, but are subordinated under divisions founded on more important characters.

The following Table exhibits Jussieu's arrangement:—

## THE JUSSIEUAN SYSTEM.

| | | | | |
|---|---|---|---|---|
| Acotyledons | | | | Class I. |
| Monocotyledons | | Stamens hypogynous | | II. |
| | | „ perigynous | | III. |
| | | „ epigynous | | IV. |
| Dicotyledons | Apetalous | Stamens epigynous | | V. |
| | | „ perigynous | | VI. |
| | | „ hypogynous | | VII. |
| | Monopetalous | Corolla hypogynous | | VIII. |
| | | „ perigynous | | IX. |
| | | „ epigynous | Anthers coherent | X. |
| | | | Anthers distinct | XI. |
| | Polypetalous | Stamens epigynous | | XII. |
| | | „ hypogynous | | XIII. |
| | | „ perigynous | | XIV. |
| | Diclinous, irregular | | | XV. |

The three primary divisions here are natural; the Classes must be regarded as artificial; the Families, however, into which the latter are divided, are natural groups, and to a great extent are retained in more modern systems. The Families of Jussieu were more carefully defined, corrected, and extended by Robert Brown, whose researches contributed most essentially to the establishment of the Natural System; but he did not attempt to establish any general plan for their coordination in Classes.

355. Aug. Pyrame De Candolle endeavoured to classify the Vegetable Kingdom on principles more in harmony with the increased knowledge of the structure of plants which had been accumulated since the promulgation of Jussieu's System. De Candolle's System has become very generally used, on account of its having been adopted in the great Descriptive work which he commenced, and which is still in progress under the superintendence of his son, the 'Prodromus Systematis Naturalis Regni Vegetabilis,' a description of all known species of plants. His primary divisions rested upon the constitution of the elementary tissues, plants being divided into *Cellular* and *Vascular*. The former were subdivided into *Leafy* and *Leafless*; the latter were subdivided into *Exogens* and *Endogens*. This classification is open to very great objections. In the first place, the *Leafless Cellular plants* stand at a greater distance from the *Leafy Cellulares* than the latter do from the lower *Vasculares*; and the character is in itself an inconvenient one. In the next place, while the terms *Exogens* and *Endogens* were founded on a mistaken idea of the structure of the stems of the higher plants, and were at the same time useless, as synonymous with Dicotyledons and Monocotyledons, the latter class was made to contain the higher Cryptogamia, the Ferns and their allies, to which an embryo was mistakenly attributed, and which are essentially related to the plants called by De Candolle *Leafy Cellulares*. These primary divisions of De Candolle are therefore now discarded.

His subdivisions of the Exogens (or more properly Dicotyledons) are retained in many works. They are artificial, like the "Classes" of Jussieu, but are, like them, convenient for the distribution of the families into groups of manageable dimensions. They are four in number, and founded on characters of the floral envelopes, viz.:— 1. *Thalamifloræ*, in which the petals are distinct and (like the stamens) inserted on the receptacle (hypogynous); 2. *Calycifloræ*, with the petals distinct or coherent and (with the stamens) inserted on the calyx (perigynous); 3. *Corollifloræ*, with the petals coherent, and inserted on the receptacle (the stamens being inserted on the corolla); and, 4. *Monochlamydeæ*, or plants with a perianth, or a single circle of envelopes.

In De Candolle's enumeration of the families, which had greatly increased in number from Jussieu's list, the reverse order of sequence is followed, the higher plants standing first. As regards this point, however, it is a misconception to place the *Thalamifloræ* first among the Dicotyledons, since they are manifestly inferior to the *Calycifloræ*, and even to the *Corollifloræ*.

## DE CANDOLLE'S SYSTEM.

A. **Plantæ Vasculares** seu **Cotyledoneæ.**
  Class I. EXOGENEÆ seu DICOTYLEDONEÆ.
    *Subclass* 1. Thalamifloræ.
    „ 2. Calycifloræ.
    „ 3. Corollifloræ.
    „ 4. Monochlamydeæ.
  Class II. ENDOGENEÆ seu MONOCOTYLEDONEÆ.
    *Subclass* 1. Phanerogamæ.
    „ 2. Cryptogamæ.
B. **Plantæ Cellulares** seu **Acotyledoneæ.**
    *Subclass* 1. Foliaceæ.
    „ 2. Aphyllæ.

The orders were arranged in groups or cohorts, and to a large extent are retained at present.

356. During the last twenty years a great many attempts have been made to distribute the Orders more satisfactorily into Classes and primary Divisions. Endlicher, Bartling, Meisner, Brongniart, Lindley, and many other authors have published Systems of their own. That of Endlicher has been extensively used, and, moreover, is the basis of arrangement in his great 'Genera Plantarum,' so that it will be useful to give the principal divisions here for comparison with others. Lindley's views of classification have been modified in successive works; but as his 'Vegetable Kingdom' is the most important general systematic work we have in the language, it is desirable to give the classification adopted in that volume. In both these Systems the primary divisions are founded on characters of the Vegetative organs; and in both an attempt is made to group the Orders into small natural assemblages, called *Classes* by Endlicher, and *Alliances* by Lindley. A comparison of these will indicate some of the diversities of opinion which exist among botanists as to the affinities of the natural Orders.

## ENDLICHER'S SYSTEM.

Region 1. **Thallophyta.**
  Sect. I. PROTOPHYTA.
  „ II. HYSTEROPHYTA.
Region 2. **Cormophyta.**
  Sect. III. ACROBRYA.
    *Cohort* 1. Acrobrya anophyta.
    „ 2. Acrobrya protophyta.
    „ 3. Acrobrya hysterophyta.

Sect. IV. AMPHIBRYA.
„ V. ACRAMPHIBRYA.
*Cohort* 1. Gymnospermæ.
„ 2. Apetalæ.
„ 3. Gamopetalæ.
„ 4. Dialypetalæ.

The cohorts are subdivided into classes, and these again into orders.

## LINDLEY'S SYSTEM.

Class I. **Thallogens.**
„ II. **Acrogens.**
„ III. **Rhizogens.**
„ IV. **Endogens.**
„ V. **Dictyogens.**
„ VI. **Gymnogens.**
„ VII. **Exogens.**
Subclass 1. DICLINOUS.
„ 2. HYPOGYNOUS.
„ 3. PERIGYNOUS.
„ 4. EPIGYNOUS.

A striking peculiarity of both these systems, Endlicher's and Lindley's, is the separation of the root-parasites, the Orders Balanophoreæ, Cytineæ, and Rafflesiaceæ, from the ordinary flowering plants, to constitute a distinct class, named Rhizanths. We agree with the views of R. Brown, Griffith, and Hooker, who regard such separation as unnatural, and the combination of these families under one head, on account of similarity of *habit*, as strongly opposed to their more essential characters. Dictyogens form a group intermediate between exogens and endogens; but by most botanists it is considered that they pertain to the latter. In Lindley's system the subclasses are divided into *alliances*, comprising each a number of *orders*, for the limitation of which, as well as for a general history of the various systems of classification that have been proposed, we refer the reader to the 'Vegetable Kingdom,' an admirable encyclopædia on all points relating to systematic botany and the uses of plants. Since the publication of that work, a very important work on systematic botany has been commenced by Mr. Bentham and Dr. Hooker, entitled 'Genera Plantarum.' This work, so far as at present published, comprises a description, in Latin, of all the genera of Polypetalous exogens, together with analytical tables admitting of the ready determination of any particular genus. The plan followed up to this time is a slight modification of the Jussieuan arrangement, as follows:—

## BENTHAM AND HOOKER'S SYSTEM.

- Class 1. **Dicotyledones.**
  - Subclass I. ANGIOSPERMEÆ.
    - Group i. *Polypetalæ.*
      - *Series* 1. Thalamifloræ.
      - ,, 2. Discifloræ.
      - ,, 3. Calycifloræ.
    - Group ii. *Monopetalæ.*
      - *Series* 1. Ovary inferior.
      - ,, 2. Ovary superior.
    - Group iii. *Monochlamydeæ.*
    - Group iv. *Achlamydeæ.*
  - Subclass II. GYMNOSPERMEÆ.
- Class 2. **Monocotyledones.**
  - Group i. *Petaloideæ.*
    - *Series* 1. Ovary inferior.
    - ,, 2. Ovary superior.
  - Group ii. *Glumaceæ.*
- Class 3. **Acotyledones.**
  - Subclass I. ACROGENS.
  - Subclass II. THALLOGENS.

Subordinate to the series are *cohorts*, or groups of orders, of equal value though with different limitations, with the *alliances* of Lindley. The only point which requires explanation here is as to the series *Discifloræ*, which includes those hypogynous polypetalous exogens in which there is a conspicuous disk or series of hypogynous glands, into, within, or upon which the stamens are inserted. The following arrangement is that adopted by Professor Henfrey in the first edition of this work, with a few slight modifications inserted with a view to bring it into harmony with other systems, and to enhance the convenience of the student:—

## SYSTEM ADOPTED IN THIS WORK.

### VEGETABLE KINGDOM.

Subkingdom I. **Phanerogamia** or **Spermocarpia** (*Flowering Plants*).

Div. I. ANGIOSPERMIA.

- Class 1. *Dicotyledones.*
  - Series 1. **Polypetalæ.**
    - Subclass 1. Thalamifloræ.
    - ,, 2. Calycifloræ.
  - Series 2. **Gamopetalæ.**
    - Subclass 3. Corollifloræ.
  - Series 3. **Apetalæ.**
    - Subclass 4. Incompletæ.
- Class 2. *Monocotyledones.*
  - Subclass 1. Spadicifloræ.
  - ,, 2. Petaloideæ.
  - ,, 3. Glumiferæ.

Div. II. GYMNOSPERMIA.

**Subkingdom II. Sporocarpia or Cryptogamia** (*Flowerless Plants*).

| Div. I. Angiosporæ. | Div. II. Gymnosporæ. |
|---|---|
| Class 1. Sporogamia. | Class 1. Hydrophyta. |
| „ 2. Thallogamia. | „ 2. Aërophyta. |
| „ 3. Axogamia. | „ 3. Hysterophyta. |

In the following systematic description of the Natural Orders, the characters of the most important are given at length, with the necessary particulars respecting their affinities, geographical distribution, and the qualities of the more important plants they contain. To most is prefixed a short diagnosis; and a similar diagnosis, or a few explanatory remarks, printed in smaller type, are accorded to those Orders which either are not marked by very decided characters, or which do not demand so much attention from the beginner. In most cases the views of other botanists as to the position and limitation of the groups are briefly mentioned. Under each Order are placed the names of one or more genera which furnish good illustrations and are generally accessible for practical examination. Comparatively few figures are given in this part of the work, since it must be strongly impressed upon the student that actual examination of plants is absolutely necessary for the acquisition of available knowledge of characters; and the substitution of drawings for descriptions in elementary works tends to encourage a superficial manner of examining plants, and to render the ideas connected with the individual Orders too abstract and too much limited to particular forms.

An artificial Key to the principal Natural Orders will be found at the end of the descriptions of the Orders.

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# CHAPTER III.

## SYSTEMATIC DESCRIPTION OF THE NATURAL ORDERS.

## THE VEGETABLE KINGDOM.

### Subkingdom I. PHANEROGAMIA, or FLOWERING PLANTS.

Plants producing stamens and pistils, and seeds containing an embryo.

### Division I. Angiospermia.

Flowering plants, with the ovules formed in closed ovaries.

### Class I. DICOTYLEDONES.

Angiospermous Flowering Plants, with stems having pith and bark separated by a compact layer of wood, which, in perennial plants, receives annual additions on the outside, beneath the bark; leaves with the ribs mostly distributed in a netted pattern and generally diminishing in size as they branch; parts of the floral circles mostly

5 or 4, or some multiple of those numbers, rarely 3; embryo with a

Fig. 328.

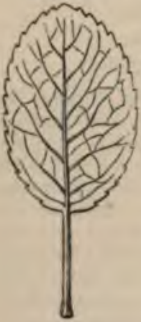


Fig. 330.

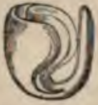


Fig. 329.

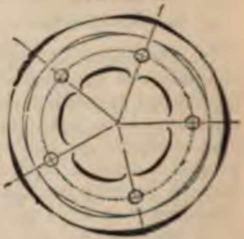


Fig. 331.

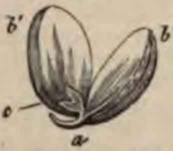


Fig. 328. Netted-veined leaf of a Dicotyledon.
Fig. 329. Quinary plan of the flower.
Figs. 330 & 331. Dicotyledonous embryos.

Fig. 333.

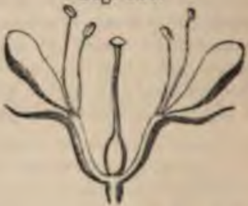


Fig. 332.

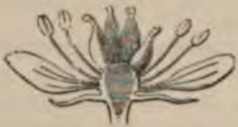


Fig. 334.

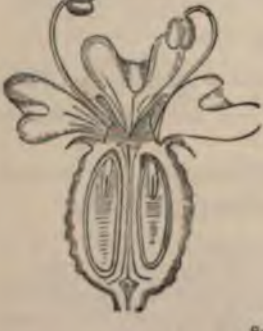


Fig. 336.

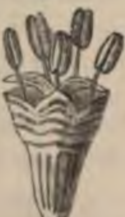
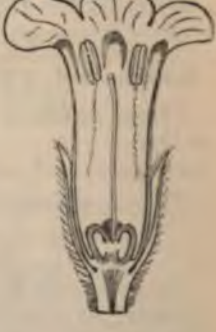


Fig. 335.



Subclasses of Dicotyledons.

Fig. 332. Thalamifloræ (*Ranunculus*).
Fig. 333. Calycifloræ (*Prunus*).
Fig. 334. Calycifloræ (*Fœniculum*).
Fig. 335. Corollifloræ (*Symphytum*).
Fig. 336. Incompletæ (Monochlamydeæ) (*Ulmus*).

pair of cotyledons, and a radicle which is developed into a tap-root in germination.

## Series 1. Polypetalæ.

Petals distinct, rarely absent or united.

## SUBCLASS 1. THALAMIFLORÆ.

357. Dicotyledons having mostly both calyx and corolla; calyx free (not adherent to the ovary); corolla composed of distinct petals, which, with the stamens, spring from the receptacle (hypogynous).

## ORDER I. RANUNCULACEÆ. THE CROWFOOT ORDER.

*Class.* Polycarpicæ, *Endl.* *All.* Ranales, *Lindl.* *Cohort.* Ranales, *Benth. et Hook.*

358. *Diagnosis.*—Herbs (or climbing shrubs) with a colourless acrid juice; leaves alternate, rarely opposite, simple or deeply divided; leaf-stalk often sheathing at the base; flowers regular or irregular, polypetalous or occasionally apetalous, with the calyx petaloid; the sepals, petals, numerous stamens, all distinct and hypogynous; carpels, many or few (rarely solitary), all distinct; seed albuminous; embryo small.

Fig. 338.

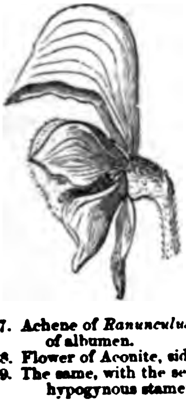


Fig. 337.

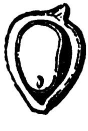


Fig. 339.

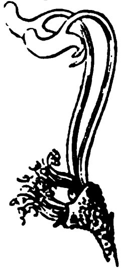


Fig. 337. Achene of *Ranunculus*, cut vertically to show the seed, with an embryo at the base of albumen.
Fig. 338. Flower of Aconite, side view, showing the irregular petaloid calyx.
Fig. 339. The same, with the sepals removed, showing the deformed petals and the numerous hypogynous stamens.

### *Character.*

*Thalamus* convex or flat, often elongated, very rarely concave. *Calyx* green or petaloid, regular or irregular (fig. 338); *sepals* 3–6, hypogynous, deciduous, occasionally persistent, usually imbricated in æstivation, sometimes valvate or induplicate.

*Corolla*: *petals* 3–15, distinct, hypogynous, in one or more rows, sometimes deformed (fig. 339) or wanting.

*Stamens* indefinite, or very rarely definite, hypogynous; *anthers* adnate, bursting longitudinally.

*Ovaries* several or few, simple, 1-celled, distinct, or very rarely coherent below to form a compound many-celled ovary; *styles* simple; *cells* 1- or many-seeded; *placentas* at the ventral sutures; *ovules* anatropous.

*Fruit*: a collection of dry achenes, a 1- or few-seeded berry, or a circle of follicles more or less coherent below, bursting at the ventral suture; *seeds* solitary, erect or pendulous, or rarely horizontal in two rows; *embryo* straight, minute, in the base or within the apex of horny *albumen* (fig. 337).

### ILLUSTRATIVE GENERA.

Tribe 1. CLEMATIDEÆ. *Mostly climbing plants with opposite leaves. Calyx valvate or induplicate: fruit of achenes, usually surmounted by the persistent and plumose style.*

Clematis, *L.*

Tribe 2. ANEMONEÆ. *Calyx usually coloured, imbricated: achenes sometimes tailed; seed inverted.*

Thalictrum, *Tournef.*
Anemone, *Haller.*
Adonis, *DC.*

Tribe 3. RANUNCULEÆ. *Calyx imbricated; achenes not tailed; seed erect.*

Ranunculus, *L.*

Tribe 4. HELLEBOREÆ. *Calyx imbricated; petals irregular or none; fruit of many-seeded follicles, more or less coherent, rarely baccate.*

Caltha, *L.*
Helleborus, *Adans.*
Nigella, *Tournef.*
Aquilegia, *Tournef.*
Delphinium, *Tournef.*
Aconitum, *Tournef.*
Actæa, *L.*

Tribe 5. PÆONIEÆ. *Calyx imbricated; petals flat or none; carpels forming dehiscent pods, surrounded at the base by a disk.*

Pæonia, *Tournef.*

**Affinities.**—The characters which are almost universally found throughout the genera of Ranunculaceæ are the free sepals and petals, the indefinite stamens, the inverted ovules, and the presence of albumen. None of these, taken separately, are absolutely characteristic of the order, though collectively they are of the greatest importance. The other characters are all more or less inconstant or variable throughout the order, some of the genera possessing them, others not. The conditions of the calyx and corolla, and also of the ripe fruit, are not only normally very varied in the different genera, but are readily affected and altered by cultivation. The affinities of the Order are somewhat complex: the structure of the essential organs allies them closely to the Magnoliaceæ and Dilleniaceæ, the former of which, however, have distinct stipules, while the latter have arillate seeds; and both differ in habit. Some genera are closely related to the Berberidaceæ, from which, however, they differ in the indefinite stamens and in the sutural (not valvular) dehiscence of the anthers. From Nymphæaceæ and Papaveraceæ, which they resemble in certain respects, they are distinguished by their distinct carpels, and in the case of the Poppies by their watery (not milky) juice. Relations exist also with some Calyciflorae, as with Rosaceæ, from which the present Order is known by its hypogynous stamens, the abundant albumen of the seeds, and the general properties. Sheathing bases of the leaves, resembling adnate stipules, occur here and in Umbelliferæ, and they somewhat resemble the stipules of *Rosa*. A kind of representation of this Order occurs among the Monocotyledons, in Alismaceæ, where the free carpels and the habit give a resemblance to those Ranunculaceæ which have a ternary calyx. The Pæonies approach the Nymphæaceæ in the disk, which is remarkably developed in *P. Moutan*, almost entirely enclosing the carpels; the stamens of Pæonies also are, owing to a slight excavation of the receptacle, perigynous rather than strictly hypogynous.

**Number and Distribution.**—This Order contains from 30 to 40 genera and a large number of species, which latter are most abundant in damp, cool climates, and are scarcely met with in the tropics, except on mountains.

**Qualities and Uses.**—The plants of this Order generally possess acrid and more or less narcotic-acrid properties, some being virulent poisons. The poisonous property resides in the watery juice, and is in most cases volatile, and capable of dissipation by heat, or even simple drying, and by infusion in water. It appears to be heightened in power by acids, spirits, sugar, &c. The species of *Ranunculus* (Crowfoots or Buttercups) are acrid when fresh, especially *R. sceleratus* and *R. Flammula*. Similar properties prevail in the tribes *Clematideæ* and *Anemoneæ*. The *Helleboreæ* are the most active of the Ranunculaceæ, the species of *Aconitum* (Monkshood) being among the most dangerous of poisonous plants, and containing an extremely powerful alkaloid, *aconitina*. The species of this genus appear to differ in the quality of their juices when grown under varied conditions, somewhat like the Hemp plant, since the roots of the most poisonous of them are said to be eaten with impunity in the higher parts of the Himalayas. The species of Aconite have been much confused by botanical writers: *A. Napellus* and *A. Cammarum* (*paniculatum*) are well-known poisonous European Monkshoods; and, according to Dr. Hooker, the celebrated "Bikh" poison of India is obtained indiscriminately from *A. Napellus*, *luridum*, and *palmatum*, as well as from *A. ferox*, L., which was supposed to be the sole source. The yellow *A. Lycoctonum* of Central Europe is far less active. The seeds of *Delphinium Staphisagria* (Stavesacre) are drastic purgatives and emetics; the Hellebores, *Helleborus niger*, *orientalis*, and *fœtida* especially, are likewise violent evacuants, and the Pæonies fall into the same category. The berries of the *Acteæ* are poisonous. Some of the milder plants are used as tonics, on account of the powerful bitter they contain, as the Yellow-root (*Hydrastis canadensis*) and the Gold-thread (*Coptis trifoliata*), both North-American plants. The pungent seeds of *Nigella sativa* were formerly used as pepper.

Many of the Ranunculaceæ are favourite garden plants: for example the species of *Clematis*, *Anemone*, *Ranunculus*, *Eranthis* (Winter Aconite), *Helleborus*, *Nigella*, *Aquilegia* (Columbines), *Delphinium* (Larkspurs), *Aconitum* (Monkshoods), and *Pæonia*. Many of them readily become double under cultivation.

## ORDER II. DILLENIACEÆ.

*Class.* Polycarpicæ, *Endl.* *All.* Ranales, *Lindl.* *Coh.* Ranales, *Benth. et Hook.*

359. *Diagnosis.*—Trees or shrubs with mostly alternate and leathery leaves, destitute of stipules; an imbricated 5-merous calyx and corolla (the former persistent); numerous hypogynous stamens; 2–5 distinct or rarely coherent carpels (sometimes 1); seeds several, 2, or 1 by abortion, arillate; albumen fleshy.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Dillenia, *L.* | Candollea, *Labill.* |
| Hibbertia, *Andr.* | Hemistemma, *Commers.* |

**Affinities.**—Connected with Ranunculaceæ by many important points of structure, these plants are at once distinguishable by the arborescent habit, the persistence of the calyx and the stamens, and the arillate seed; they are even nearer to the Magnoliaceæ, but have no stipules, and the plan of the flower is here 5-merous; they are also related to the Anonaceæ, which, however, have a valvate calyx and ruminated albumen. Some of the genera (*Hemistemma*, *Pleurandra*) have all the stamens on one side of the flower; others have them united into separate bundles. A relationship between this Order and the Ternstrœmiaceæ is established by the genus *Sauraja*.

**Number and Distribution.**—A small group, the species of which are natives chiefly of India, South America, and Australia; a few also of Africa, between the tropics.

**Qualities and Uses.**—The general character of this Order is astringency, which renders some of them valuable in Brazil. Some of the *Dilleniæ* are valued in India for their acid juices.

Most of the species of *Dillenia* are very handsome, both as to foliage and blossom; and some of the larger kinds yield hard, durable timber; several species are cultivated in large collections of stove or greenhouse plants in this country, where they are evergreen shrubs; *Delima* and *Tetracera* are stove climbers.

## ORDER III. MAGNOLIACEÆ.

*Class.* Polycarpicæ, *Endl.* *All.* Ranales, *Lindl.* *Coh.* Ranales, *Benth. et Hook.*

360. *Diagnosis.*—Trees or shrubs, with the leaf-buds mostly sheathed by membranous stipules; leaves alternate, simple; flowers regular, polypetalous, hypogynous, polyandrous, polygynous; the calyx and corolla coloured alike, in three or more 3-merous circles, imbricated in the bud; fruit of numerous dry or succulent, dehiscent or indehiscent carpels; the seeds often with a fleshy testa like an

aril, and suspended by a long funiculus; albumen fleshy, homogeneous.

ILLUSTRATIVE GENERA.

| Tribe 1. MAGNOLIEÆ. *Carpels arranged in a cone; leaves scarcely dotted.* | Tribe 2. WINTEREÆ. *Carpels in a circle; leaves with transparent dots; stipules often wanting.* |
|---|---|
| Magnolia, *L.* | Drimys, *R. Br.* |
| Liriodendron, *L.* | Illicium, *L.* |

**Affinities.**—Closely related to Dilleniaceæ, this Order is distinguished by the 3-merous flowers, and in many cases by its stipules; from the Anonaceæ it is separated by its imbricated corolla and its homogeneous albumen. The convolute stipules enclosing the leaf-buds of *Magnolia* remind us of the stipules of *Ficus* and other Urticaceæ. The character of the flowers indicates a relationship with Schizandraceæ, which, indeed, are combined with them by Bentham and Hooker.

**Number and Distribution.**—A small group, the greater number of which belong to the Southern States of North America; some occur also in the West-India Islands, in Japan, China, and India. *Drimys* and *Tasmannia* belong to the extreme south of South America, to Australia, and New Zealand.

**Qualities and Uses.**—Bitter tonic properties in the bark and excessively fragrant blossoms are the most striking qualities of the plants of this Order, which are chiefly handsome trees or shrubs, with broad shining foliage and often very large flowers. The barks of *Magnolia glauca, grandiflora, Frazeri*, &c. are used extensively in the United States as aromatic tonics; *Michelia montana, Aramodendron elegans*, and *Liriodendron tulipifera* have similar properties. The odour of *Magnolia grandiflora*, commonly cultivated in this country, and of *M. glauca* and *M. tripetala*, is so powerful as to become very oppressive in close places; the last two often induce headache, and, it is said, sickness, and even fever. The species of *Illicium* are aromatic: *Illicium anisatum*, Star-Anise, is so called from the flavour of aniseed in the whole plant, especially the fruit, which yields an aromatic oil. *I. floridanum* has similar properties; and the seeds of *I. religiosum* are burnt in their temples by the Chinese for incense. The bark called Winter's bark is that of *Drimys Winteri*; and other species of *Drimys* and *Tasmannia* have similar aromatic and tonic properties. Some of the larger species of *Magnolia*, *Michelia*, and other genera are valued as timber trees in India. Many plants of this Order are cultivated in this country on account of their beauty or fragrance; some are hardy, as various Magnolias and the Tulip-tree (*Liriodendron*) from North America. Some of the Chinese and Himalayan Magnolias have deciduous foliage and magnificent flowers, such as *M. Campbelli* and *M. Yulan*; others are greenhouse or stove shrubs, such as the species of *Illicium* and the more tender Magnolias.

## ORDER IV. ANONACEÆ. THE CUSTARD-APPLE ORDER.

*Class.* Polycarpicæ, *Endl.* *All.* Ranales, *Lindl.* *Coh.* Ranales, *Benth. et Hook.*

361. *Diagnosis.*—Trees or shrubs with naked buds and no stipules; thalamus usually convex; calyx of three sepals; corolla of six petals in two circles, usually valvate in the bud, hypogynous, sometimes coherent; stamens with an enlarged connective, mostly indefinite, on a large torus; carpels usually numerous, separate or cohering; seed with ruminated albumen.

### ILLUSTRATIVE GENERA.

Bocagea, *St.-Hil.*
Xylopia, *L.*
Uvaria, *L.*
Duguetia, *St.-Hil.*
Anona, *L.*
Monodora, *Dun.*

**Affinities.**—This Order is separated from the Magnoliaceæ in general by the absence of stipules, the valvate æstivation of the corolla, and the form of the anthers; but stipules are not universal in the Magnoliaceæ, nor is the corolla always valvate here. The most characteristic features in the Anonaceæ are the trimerous flowers, the double corolla, the form of the anthers and carpels, and the ruminated albumen, which latter indicates a relationship to the Myristicaceæ, an apetalous Order. Several remarkable deviations from the general character of the Order exist, such as the coherent condition of the horn-like petals in *Rollinia*, the definite number of stamens and carpels in *Bocagea* (which is related to the Berberidaceæ and the Menispermaceæ), and the concave thalamus, the sepals and petals combined to form a hood, and the perigynous stamens of *Eupomatia laurina*. *Monodora* has a single carpel.

**Number and Distribution.**—A not very numerous family, the species are natives of the tropical regions of Asia, Africa, and America.

**Qualities and Uses.**—The Anonaceæ are allied to the Magnoliaceæ by their general aromatic and fragrant properties. The dry fruits are mostly aromatic and pungent, while the succulent kinds are sweet and agreeable esculent fruits. The Custard-apples, Sweet-sops, and Sour-sops of the West Indies, and the Peruvian Cherimoyas are the fruits of species of *Anona*. The fruits of *Xylopia aromatica* are used as pepper by the African negroes (*Piper æthiopicum*). *Monodora Myristica*, the Calabash Nutmeg, has qualities resembling the true Nutmeg. Lance-wood, used for making shafts, bows, &c., is said by Schomburgk to be the wood of *Duguetia quitarensis*. Some of the species of *Anona*, *Uvaria*, *Xylopia*, &c. are sometimes cultivated in stoves in this country, forming evergreen shrubs.

(The MONIMIACEÆ are aromatic trees or shrubs with opposite leaves without stipules; flowers axillary, diclinous; perianth in 1 or 2 circles, tubular below; stamens numerous, in the tube; ovaries several, free, and distinct, enclosed in the tube of the perianth, 1-celled, 1-seeded; seeds pendulous; embryo minute, on the outside of abundant fleshy albumen. This is a small Order of plants belonging chiefly to South America, but occurring also in Madagascar, Java, Australia, &c.; sometimes combined with the next family, and usually referred to the neighbourhood of Lauraceæ, from which they are distinguished by their apocarpous ovaries, but, like the Atherospermaceæ, standing properly in the vicinity of the Anonaceæ, along with Myristicaceæ; for some genera are dichlamydeous. They are also related to Calycanths and Roses, but they differ from these Orders in their opposite exstipulate leaves and albuminous seeds. Bentham and Hooker place them near Magnoliaceæ, to which their aromatic properties ally them. They are not of importance economically; the fruit of *Boldoa* is eaten in Chili. Genera: *Monimia*, Thouars; *Citrosma*, R. & P.; *Boldoa*, Juss.; *Hortonia*, Wight.)

## ORDER V. MENISPERMACEÆ. THE MOON-SEED ORDER.

*Class.* Polycarpicæ, *Endl.* *All.* Menispermales, *Lindl.* *Coh.* Ranales, *Benth. et Hook.*

362. *Diagnosis.*—Woody climbers, with palmate or peltate alternate leaves, without stipules; flowers diœcious, rarely perfect or polygamous; sepals and petals similar, in three or more circles, imbricated or valvate in the bud; stamens usually 6, opposite the sepals and petals; pistil 3–6-gynous; fruit a 1-seeded drupe, with a large or long curved embryo in scanty albumen.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Anamirta, *Coleb.* | Cissampelos, *L.* |
| Jateorrhiza, *Miers.* | Cocculus, *DC.* |
| Menispermum, *Tournef.* | |

**Affinities.**—This curious Order is related to the Anonaceæ and the Berberidaceæ through *Bocagea*, especially when the flowers are perfect. Its nearest neighbours are Lardizabalaceæ and Schizandraceæ, with which the plants agree much in habit. All these approach the Magnoliaceæ; but the habit, the generally unisexual flowers, and the absence of stipules separate them from that family.

This Order is very heteromorphous in almost all parts of its structure. The peculiar organization of the wood deserves attention, as does also the foliage.

**Number and Distribution.**—A somewhat numerous group, the species of which are natives of the tropics of Asia and America, forming woody climbers of great size in the forests. A few are found in more temperate regions, but none in Europe.

**Qualities and Uses.**—Narcotic and bitter properties of considerable power occur in this Order. "Cocculus Indicus," containing the poisonous principle picrotoxine in the seeds, consists of the berries of *Anamirta paniculata*; *Jateorrhiza Columba* furnishes "Calumba-root;" different species of *Cissampelos*, especially *C. Pareira* ("Pareira brava"), are used as tonics and diuretics.

Species of *Cocculus* and *Cissampelos* are grown in stoves in this country; some of the North-American *Menisperma* grow as hardy climbers here.

## ORDER VI. LARDIZABALACEÆ.

363. A small group, referred by Bentham and Hooker to Berberids, and by DeCandolle to Menisperms. From the former they differ in their diclinous flowers, monadelphous stamens, sutural dehiscence of the anthers, and more numerous ovaries. From the latter they differ in their more numerous ovules and small embryo in copious solid albumen.

### ILLUSTRATIVE GENERA.

Hollbœllia, *Wall.* | Stauntonia, *DC.* | Lardizabala, *Ruiz et Pav.*

The species are mostly from the cooler parts of Asia and South America. The berries of some are edible. *Hollbœllia* and *Stauntonia* (Nepal) have been introduced as greenhouse evergreen climbers.

## ORDER VII. SCHIZANDRACEÆ.

364. A small family regarded by Bentham and Hooker as a tribe of Magnoliaceæ (see p. 201), from which they differ merely in their climbing habit, exstipulate leaves, diclinous flowers, and fleshy 2–3-seeded carpels.

### ILLUSTRATIVE GENERA.

Kadsura, *Juss.*
Hortonia, *Wight.*
Sphærostema, *Blum.*
Schizandra, *L. C. Rich.*

The species belong to India, Japan, and the S. United States. They are insipid and mucilaginous. *Schizandra coccinea* (North America) is a handsome greenhouse plant; *Sphærostema* (Nepal) has been introduced in stoves.

(A small Order of East-Indian plants, SABIACEÆ, are related to the Menispermaceæ in the circumstance that the sepals, petals, stamens, and ovaries are all placed "opposite" to each other, but they have 5-merous hermaphrodite flowers and a syncarpous pistil. By Bentham and Hooker they are placed near Sapindaceæ.)

## ORDER VIII. BERBERIDACEÆ. THE BERBERRY ORDER.

*Class.* Polycarpicæ, *Endl.* *All.* Berberales, *Lindl.* *Coh.* Ranales, *Benth. et Hook.*

365. *Diagnosis.*—Shrubs or herbs, with regular hermaphrodite flowers, with the sepals and petals both imbricated in the bud in 2 or more circles of 2–4 each (fig. 340); hypogynous stamens as many as the petals and opposite to them; anthers opening by 2 recurved valves.

### *Character.*

*Calyx* with 3–4–6 deciduous *sepals*, surrounded by petaloid scales.

*Corolla*: *petals* hypogynous, as many as the sepals and opposite to them, or twice as many, sometimes with a basal appendage inside.

*Stamens* equal in number to the petals and opposite to them, the 2-celled *anthers* opening by a recurved valve to each cell, or rarely suturally (*Podophyllum*).

*Pistil*: *carpel* solitary, free, 1-celled; *style* somewhat lateral; *stigma* orbicular; *placenta* sutural; *ovules* anatropous, numerous or in pairs, ascending or suspended.

*Fruit* baccate, or dry; *seeds* crustaceous or membranous; embryo straight in the centre of fleshy or horny albumen.

### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Berberis, *L.* | Epimedium, *L.* | Caulophyllum, *Michx.* |
| (*Mahonia*, Nutt.) | Leontice, *L.* | Jeffersonia, *Bart.* |

**Affinities.**—To Ranunculaceæ this Order is related closely by *Jeffersonia* and *Podophyllum*. *Epimedium* allies the Order to Fumariaceæ. The connexion with the Anonaceæ through *Bocagea* has been referred to above. They differ from Menisperms, to which their floral arrangements ally them, in their hermaphrodite flowers and small embryo. The remarkable mode of dehiscence of the anthers connects this Order in that respect with Lauraceæ and Atherospermaceæ among the Monochlamydeæ. *Caulophyllum thalictroides*, a North-American plant, is interesting from the development of its fruit; the pericarp dehisces very early, and the two seeds burst out and ripen into naked berry-like bodies with a succulent testa. The leaves of these plants are simple or compound, sometimes reduced to the condition of spines (§ 103). The ripe anthers possess a peculiar irritability, which causes their valves to turn back and burst when touched.

Fig. 340.

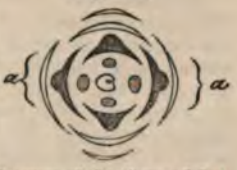


Diagram of the flower of *Epimedium*: *a*, *a*, bracteoles.

**Distribution.**—A small Order, the species of which are natives of temperate climates in America, Europe, and the northern part of India.

**Qualities and Uses.**—The bark of the root of some of the Indian species contains a bitter principle, on which account it is used as a tonic in fevers in lieu of quinine. The Berberry (the fruit of *Berberis vulgaris*) and the fruits of other species are acid and astringent, and are eaten preserved. The stem and bark are used by dyers, both on account of their astringent properties and as ingredients in a yellow dye. The rhizome of *Podophyllum peltatum* furnishes a resin which has purgative properties, and is much used as a substitute for mercury. The leaves of this plant are narcotic; but the berries are edible.

*Berberis vulgaris* is a British plant, often cultivated on account of its beautiful scarlet berries; the evergreen Berberaceæ, *B. Aquifolium*, &c. (*Mahonia*, Nutt.), are also extensively planted on account of their shining pinnate leaves and the grey bloom on their black berries. *Epimedium alpinum* is a rare British plant, found in the northern counties.

## ORDER IX. NYMPHÆACEÆ. WATER-LILIES.

*Class.* Nelumbia, *Endl.* *All.* Nymphales, *Lindl.* *Coh.* Ranales, *Benth. et Hook.*

366. *Diagnosis.*—Aquatic herbs with cordate or peltate floating leaves, and solitary showy flowers, proceeding from a rhizome growing at the bottom of the water; the partially petaloid sepals and the numerous petals and stamens imbricated in several rows are partially or wholly adherent to a large fleshy disk; the numerous carpels combined into a many-celled compound ovary, with radiating stigmas on the top; ovules all over the spongy dissepiments; embryo minute, enclosed in a separate sac at the end of the copious albumen.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Nymphæa, *Neck.* | Victoria, *Lindl.* |
| Nuphar, *Smith.* | Euryale, *Salisb.* |

**Affinities.**—The relations of this striking Order are varied, and some difference of opinion exists among botanists even as to their position in the two great classes of Angiospermous Flowering plants. The embryo appears to be truly Dicotyledonous; and if we range the Nymphæaceæ in that class, they naturally approach the Papaveraceæ in the character of the ovary, and with these likewise the Pæony tribe among the Ranunculaceæ, especially the kinds with a highly developed disk. The character of the floral envelopes and stamens allies them to the Magnoliaceæ. The Nelumbiaceæ and Cabombaceæ are immediately connected with them. From a mistaken view of the structure of the seed, regarding the vitellus or amniotic inner endosperm as a cotyledon (§ 299), Richard assumed that this Order was Monocotyledonous; and although it has proved that this account of the structure of the embryo was incorrect, the plants are so anomalous in many respects, that it is difficult to decide as to their closest relationships. The structure of the rhizomes is quite that of Monocotyledonous stems; the habit relates them to the Hydrocharidaceæ; and the structure of the ovaries indicates some affinity with Alismaceæ. When, however, we regard the Dicotyledonous embryo and its germination, the quaternary or quinary plan of the flowers, and the netted ribbing of the leaves, together with its close relation to the Dicotyledonous Orders above named, the balance of characters is strongly in favour of its reference to this Class. Nymphæaceæ are very interesting in structural respects—as, for example, in the anomalous condition of the rhizomes, the remarkable development of the leaves in *Victoria*, the curious succession of forms between petals and stamens in the many-whorled envelopes of the flowers of *Nymphæa* and *Victoria*, the various degrees of development of the disk and enlarged receptacle, ranging from *Nuphar* with a superior ovary to *Victoria* with its ovary sunk in the receptacle and its stamens and envelopes raised on an annular disk, the seeds growing all over the dissepiments, and in the peculiar condition of the albumen.

**Distribution.**—A small family, the species of which are distributed throughout the world, more rarely in the southern hemisphere.

**Qualities and Uses.**—These plants are said, on doubtful authority, to be sedative and narcotic. More important characters arise from the presence of starch in the seeds of various kinds of *Nymphæa*, of *Euryale* and *Victoria*, which are used as food. The corn-like rhizomes of some Nymphæas are eaten in Scinde, others in Western Africa. Among the most remarkable plants of the Order is the *Victoria regia*, a native of the rivers of equatorial America, with its enormous circular leaves and beautiful flowers. Our native Water-lilies, the white (*Nymphæa alba*) and yellow (*Nuphar lutea*), are both striking objects, and the cultivated *Nymphæa cærulea* and the crimson *N. rubra* illustrate the brilliancy and variety of colour in this beautiful Order. *N. gigantea*, a blue-flowered Australian species, has flowers almost as large as those of the *Victoria*.

(CABOMBACEÆ, consisting of only two species, of the genera *Cabomba* and *Brasenia* (*Hydropeltis*), are sometimes separated from Nymphæaceæ, of which they are a reduced form, with definite sepals and petals, hypogynous stamens, and distinct carpels with styles inserted on a flattened torus, and containing one or two ovules on the dorsal suture. They are closely allied to Ranunculaceæ, but differ in the embryo enclosed within a double albumen. Both genera occur in America, and *Brasenia* also in the East Indies and Australia.)

## ORDER X. NELUMBIACEÆ. WATER-BEANS.

367. Large aquatic plants, like Water-lilies, but with distinct carpels, forming acorn-shaped nuts separately imbedded in cavities of a large top-shaped receptacle. Seeds solitary, exalbuminous.

**Affinities, &c.**—This Order consists apparently of the two species of *Nelumbium*—*N. speciosum*, supposed to be the Sacred Egyptian Bean, found throughout the East Indies, but no longer in Egypt, and *N. luteum* in North America. They are nearly related to Nymphæaceæ, through Cabombaceæ; and both are included in that family by Bentham and Hooker. The enlarged receptacle of the fruit is very curious, and the peltate leaves raised above the water on long stalks are remarkable objects. The nuts are the ripened carpels, which are contained in separate sockets in the top of the receptacle; the seeds have large flat fleshy cotyledons applied against the plumule, which is unusually developed. The seeds, as also the tubers of *N. luteum* and the rhizomes of *N. speciosum*, are esculent, being full of farina at certain seasons.

## ORDER XI. SARRACENIACEÆ.

368. Polyandrous and hypogynous Bog-plants, with hollow pitcher-shaped or trumpet-shaped leaves, and regular polyandrous hypogynous flowers.

ILLUSTRATIVE GENERA.

Sarracenia, *L.* | Heliamphora, *Benth.* | Darlingtonia, *Torr.*

**Affinities, &c.**—These curious plants, chiefly remarkable for their anomalous leaves, forming *ascidia* (§ 101) or pitchers, are few in number, consisting of a few species of *Sarracenia* in the United States, a *Darlingtonia* in California, and *Heliamphora* in Guiana. *Sarracenia* has a very large, angular, peltate stigma, while that of *Heliamphora* is simple and truncate. They are regarded as related to Ranunculaceæ by the 4–5-merous and imbricated envelopes and the numerous hypogynous stamens, while the coherence of the carpels into a compound ovary brings them at the same time near Papaveraceæ; but the placentas are axile.

## ORDER XII. PAPAVERACEÆ. THE POPPY ORDER.

*Class.* Rhœades, *Endl.* *All.* Ranales, *Lindl.* *Coh.* Parietales, *Benth. et Hook.*

369. *Diagnosis.*—Herbs with milky (white or coloured) juice, alternate exstipulate simple or lobed leaves; flowers regular, 2-merous or 4-merous; sepals caducous; polyandrous; hypogynous; ovary syncarpous, 1-celled, with 2 or many parietal placentas.

### *Character.*

*Calyx*: *sepals* 2, rarely 3, caducous.

*Corolla*: *petals* 4, rarely 6, hypogynous, mostly crumpled up in æstivation.

*Stamens* free and distinct, indefinite, hypogynous; *anthers* 2-celled, bursting longitudinally.

*Ovary* free, composed of 2 or more carpels (very rarely distinct), 1-celled; *ovules* numerous, very rarely solitary; *placentas* broad, parietal, on the projecting incomplete dissepiments; *style* short or none; *stigmas* radiating, double, opposite the imperfect dissepiments; *ovules* anatropous or amphitropous.

*Fruit* capsular (fig. 342) with a number of placentas on imperfect septa, or pod-shaped with parietal placentas, the dehiscence valvular or porous; *seeds* mostly numerous; *embryo* minute, straight, at the base of fleshy oily albumen.

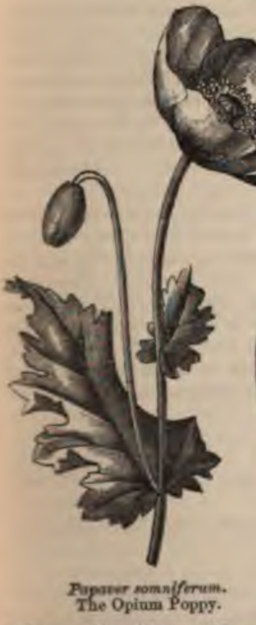
### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Chelidonium, *Tournef.* | Papaver, *Tournef.* | Eschscholtzia, *Cham.* |
| Argemone, *Tournef.* | Glaucium, *Tournef.* | Platystemon, *Benth.* |

**Affinities.**—Taking the common Poppies as types of this Order, we find a marked distinction from Ranunculaceæ in the 2-merous calyx, the confluent carpels, and the milky juice; but the first two of these characters do not hold universally, since *Argemone* has sometimes 3 sepals, and *Platystemon* has the carpels more or less distinct, or united only slightly externally. *Bocconia*, with small flowers and no petals, approaches to *Thalictrum*. Monstrous capsules of *Papaver* occur in gardens with the carpels partly free, somewhat as in *Nigella*. This Order is also related to the

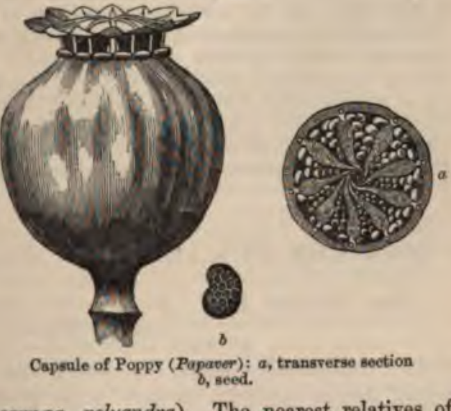
Nymphæaceæ by the general structure of the flower of *Papaver*; and the dissepiments extend quite to the axis in the Californian genus *Romneya*. Another genus from the same region, *Dendromecon*, has peculiar double-lined parietal placentas, and the capsule bursts into 2 valves with the seeds on the margins, as in Cistaceæ. The quaternary arrangement of the floral envelopes and the pod-shaped ovary of *Eschscholtzia*, *Glaucium*, *Chelidonium*, &c. cause a close resemblance to Cruciferæ and Capparidaceæ, from which, however, there is a marked distinction in the albuminous seeds and the narcotic milky juice; the tetradynamous stamens of Cruciferæ, too, almost always afford a striking character; but a remarkable exception has been lately observed in an East-Indian polyandrous Crucifer (*Megacarpæa polyandra*). The nearest relatives of the Papaveraceæ are the Fumariaceæ, which are combined with them as an irregular form by some authors. The agreement is great in many respects; but the Fumariaceæ have irregular flowers, diadelphous stamens, and a watery juice: the genus *Hypecoum*, however, has the corolla nearly regular, and its 4 stamens are distinct; and *Meconella*, in the present Order, has but 4–5 stamens; so that *Hypecoum* is midway as it were between the Orders.

Fig. 341.



*Papaver somniferum*.
The Opium Poppy.

Fig. 342.



Capsule of Poppy (*Papaver*): *a*, transverse section *b*, seed.

The structural points most worthy of note here are the varied conformation of the ovary, and the peculiar construction of the stigmas by two lamellæ from adjoining carpels. There is a curious enlargement of the receptacle of *Eschscholtzia*, with circumscissile separation of its coherent caducous sepals in the form of a conical cap. The stamens and petals, moreover, become perigynous in this genus. The sepals in most cases fall off when the flowers expand, so that they must be observed in unopened flowers. Milky juice, or rather juice which turns milky when exposed to the air, seems universal in this Order.

**Distribution.**—The group is not a large one; but the species occur in all parts of the globe, but sparingly out of Europe (in a wild state).

**Qualities and Uses.**—The milky juice of Papaveraceæ is very generally powerfully narcotic, sometimes acrid. *Papaver somniferum*, the Opium Poppy (fig. 341), is the most important plant of the Order, the opium consisting of the dried milky juice obtained from the unripe capsules (fig. 342). Its native country is unknown; but it is largely cultivated in Turkey and the East Indies. Its seeds yield a fixed oil, which is quite harmless and is used both by itself and as a means of adulterating olive-oil; the oil-cake is also used for feeding cattle. The seeds of *Argemone mexicana* are narcotic-acrid. The yellow acrid juice of *Chelidonium majus*, as also that of *Bocconia frutescens*, is poisonous, and is sometimes used as an escharotic. *Sanguinaria canadensis*, the Blood-root or Puccoon, receives the former name from the red juice of its root, which is employed in North America for its emetic and purgative properties. *Meconopsis nepalensis* is said to be very poisonous, especially in the roots.

Several plants of this Order are wild in this country, as the four kinds of Red Poppy of our fields, the commonest of which is *Papaver Rhœas*. *P. somniferum* is a corn-field weed in many places on chalky soil; and its numerous double varieties are to be found in most gardens. *Glaucium luteum*, the yellow Horned Poppy, grows on our sea-shores; *Chelidonium majus* grows about hedges near villages, and is apparently an outcast from gardens; the other native plants of this Order are less common. *Eschscholtzia*, a Californian genus, is now found in every garden; and *Platystemon*, *Argemone*, and other genera are also cultivated here.

## ORDER XIII. FUMARIACEÆ. THE FUMITORY ORDER.

*Class.* Rhœades, *Endl.* *All.* Berberales, *Lindl.* *Coh.* Parietales, *Benth. et Hook.*

370. *Diagnosis.*—Delicate smooth herbs with watery juice, dissected leaves, irregular flowers, with 4 partially united petals, 6 diadelphous or 4 distinct stamens; ovary 1-celled, 1-seeded, or several-seeded with two parietal placentas.

### *Character.*

*Calyx*: *sepals* 2, caducous.

*Corolla*: *petals* 4, irregular, in 2 circles.

*Stamens* hypogynous, rarely 4 and distinct, opposite to the petals, or 6, diadelphous, the parcels opposite to the outer petals each with a central 2-celled anther and 2 lateral 1-celled anthers.

*Ovary* free, 1-celled; *style* filiform; *stigma* with 2 or more points; *ovules* horizontal, amphitropous.

*Fruit*: an indehiscent 1- or 2-seeded nut, or a dry 2-valved or succulent indehiscent many-seeded pod; *seeds* shining, mostly arillate; *embryo* minute, abaxial, straight or curved, in fleshy albumen.

### ILLUSTRATIVE GENERA.

Dicentra, *Borkh.* | Fumaria, *Tournef.* | Hypecoum, *Tournef.*

**Affinities.**—The close relationship to Papaveraceæ has been pointed out. Bentham and Hooker indeed include Fumitories under that family, *Hypecoum*, with its four distinct stamens, diverges from the ordinary type immediately towards that Order. The number, form, and arrangement of the floral envelopes mark an affinity to the Berberidaceæ, which likewise have stamens opposite to the petals. A further relationship exists in the direction of Cruciferæ, concerning which, however, authors are at variance, on account of the curious condition of the diadelphous stamens here. As stated above, the two parcels each bear a central 2-celled anther with a single anther-lobe on each side. Lindley and Asa Gray regard these parcels as formed from four stamens, the two lateral of which are *split*, sending half an anther to the posterior, and the other half to the anterior parcel, offering an illustration of *chorisis* (§ 149): this would be in agreement with the four stamens of *Hypecoum*; but six are said to occur here sometimes, which would favour Gay's view, that the plan of the stamens is like that of Cruciferæ, and their normal mumber 6. Probably there are but two stamens originally, from which the lateral ones are subsequently produced. Lindley is also inclined to think that the so-called sepals are really bracts, and the two outer petals sepals, which would render the position of the staminal bundles opposite the outer petals (sepals) normal; but the relationship to Berberidaceæ is against this. The mode in which the horned stigmas push themselves against the extrorse anthers in the blossom of *Fumaria*, while the petals cohere by their tips, is worthy of examination, as also are the modifications of the staminal bundles in *Fumaria*, *Dicentra*, &c. The long pod of *Hypecoum* has transverse spurious septa between the seeds.

**Distribution.**—The species are not very numerous, and are mostly found in the temperate parts of the Northern Hemisphere.

**Qualities and Uses.**—Mild bitter, sometimes rather acrid, and with slight diaphoretic and aperient properties, but of little importance in this respect. The genus *Fumaria* has a number of rather doubtful species in this country, *Corydalis claviculata* is not very rare in woody places; and several tuberous-rooted species of *Corydalis* are found as hardy herbaceous plants in our gardens. *Dicentra* (*Dielytra*) *spectabilis*, a handsome Chinese species, is now greatly cultivated as an early-flowering greenhouse plant, which is hardy in some situations.

## ORDER XIV. CRUCIFERÆ. CROSS-FLOWERS.

*Class.* Rhœades, *Endl.* *All.* Cistales, *Lindl.* *Coh.* Parietales, *Benth. et Hook.*

371. *Diagnosis.*—Herbs with a pungent watery juice, cruciform 4-merous flowers, and tetradynamous stamens; fruit a silique or silicle; seed exalbuminous.

### *Character.*

*Calyx*: *sepals* 4, deciduous, imbricated or valvate in the bud.

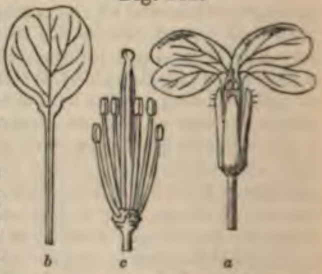
*Corolla*: *petals* 4, distinct, stalked, arranged in the form of a cross, alternating with the sepals (fig. 343).

*Stamens* tetradynamous (fig. 344), a single short one opposite each lateral sepal, and a pair of long ones opposite the anterior and the posterior sepals, with small *glands* intervening between the stamens on the receptacle.

*Ovary* solitary, 2-celled by a spurious dissepiment (*replum*) extending across from the middle line of the two parietal placentas; *stigmas* 2, sessile, opposite the placentas.

*Fruit*: a *silique* (fig. 346) or a *silicle* (fig. 347), usually 2-celled by the replum, from which the valves separate in dehiscence, leaving the placentas as a frame; or 1-celled from the imperfection of the replum (fig. 347), and indehiscent or breaking across at constricted places; *seeds* generally pendulous in a single row on each placental margin, the two rows either intercalated in one line or in two collateral lines on the replum; *embryo* with the radicle variously folded on the cotyledons, without albumen.

Fig. 343.



*Raphanus*: *a*, cruciform flower; *b*, stalked petal; *c*, tetradynamous stamens.

De Candolle has divided this large and very natural Order into Suborders, founded on the mode of folding of the embryo, thus:—1. *Pleurorhizæ* (0=), with the radicle turned round the sides or edges of the flat, accumbent cotyledons; 2. *Notorhizæ* (0‖), with the radicle folded against the back of one of the flat, incumbent cotyledons; 3. *Orthoploceæ* (0>>), the radicle similarly folded, but the incumbent cotyledons longitudinally folded (induplicate) so as partly to surround it; 4. *Spirolobeæ* (0‖‖), the cotyledons linear, incumbent, and folded or rolled over on themselves and against the radicle;

5. *Diplecolobeæ* (0|| || ||), the cotyledons linear, incumbent, and twice or thrice transversely folded.

Fig. 344.

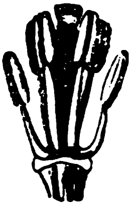


Fig. 346.

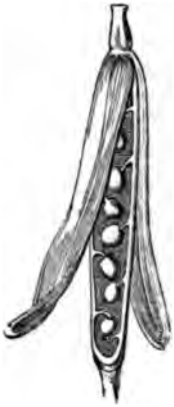


Fig. 345.

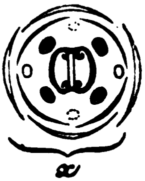


Fig. 344. Stamens and pistil of *Cheiranthus*.
Fig. 345. Ground-plan of the flower of *Cheiranthus*: *x*, the front.
Fig. 346. Burst silique of *Sinapis*.

Some writers establish Suborders on the characters of the fruit, using those of the embryo for subdivision, thus:—1. *Siliquosæ*, with a silique opening by valves; 2. *Siliculosæ latiseptæ*, with a silicle opening by valves, the replum in the broader diameter; 3. *Siliculosæ angustiseptæ*, a valved silicle with the replum in the narrower diameter; 4. *Nucumentaceæ*, with an indehiscent silicle, often 1-celled without a replum; 5. *Septulatæ*, with the valves bearing transverse septa in the inside; 6. *Lomentaceæ*, with a pod breaking across into 1-seeded pieces, sometimes with a 1–2-seeded beak above the abortive true pod. Bentham and Hooker's arrange-

Fig. 347.

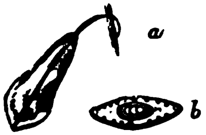


Fig. 348.

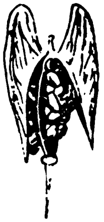


Fig. 349.

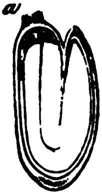


Fig. 347. Silicle of *Isatis*: *a*, entire; *b*, cross section.
Fig. 348. Burst silicle of *Thlaspi*.
Fig. 349. Seed of *Erysimum* cut vertically: *a*, funiculus.

ment closely corresponds with this; but the Suborders are all more or less artificial.

### ILLUSTRATIVE GENERA.

Cheiranthus, *R. Br.*
Matthiola, *R. Br.*
Nasturtium, *R. Br.*
Arabis, *L.*
Aubrietia, *Adans.*
Alyssum, *L.*
Erophila, *DC.*
Cochlearia, *L.*
Thlaspi, *Dill.*
Iberis, *L.*
Cakile, *Tournef.*
Malcolmia, *R. Br.*
Hesperis, *L.*
Sisymbrium, *L.*
Erysimum, *L.*
Capsella, *Vent.*
Lepidium, *R. Br.*
Brassica, *L.*
Sinapis, *Tournef.*
Crambe, *Tournef.*
Raphanus, *Tournef.*
Senebiera, *Poir.*
Subularia, *Adans.*
Schizopetalon, *Hook.*

**Affinities.**—The relationships of this Order to Papaveraceæ and Fumariaceæ, and thence with the Apocarpous Orders standing near, have been dwelt on already. With the Capparidaceæ the agreement is still closer, in the general character of the flower and in the seeds; but when that Order has so few as six stamens they are not tetradynamous—an almost universal condition in Cruciferæ. The true nature of the plan of the anomalous flower of this Order is a subject of considerable controversy. The two lateral sepals are attached higher up than the other two, the four petals are in a single row. Lindley and many others regard the six stamens as belonging to two circles of four, the outer of which has always two stamens abortive, while the inner pairs should normally stand singly before the four petals: if the glands in the receptacle are to be regarded as abortive stamens, which is plausible, this structure really does exist in *Erysimum Peroffskianum*, where the two glands stand opposite two sepals and form a circle with the two short stamens; but there appear to be as many as six glands in some Crucifers, which involves the existence of three staminal circles: as a polyandrous form (*Megacarpæa polyandra*) has been met with, we may even admit this. Moquin-Tandon and Webb regarded the stamens as normally four, the pairs being formed by *chorisis* (§ 149). As to the ovary, it seems most simply explained as composed of two carpels with a spurious dissepiment, the stigmas opposite the placentas, like those of *Papaver*, being double and composed of a half from each carpel, just as the placentas are. The fact that four carpels are sometimes found in monstrosities, and are constant in the genus *Tetracellion*, merely indicates a return to a symmetrical condition, ordinarily interfered with by suppression of two carpels. The most recent views as to the structure of the flower are those of Eichler, who affirms the existence of chorisis in the long stamens. His notion is that the flowers of Crucifers consist of two antero-posterior sepals, two lateral ones, four petals crossing the lateral sepals diagonally, two lateral short stamens, two antero-posterior long stamens split into two, and two lateral carpels. These views are adopted after an examination of the development of the flower, in which there are first to be seen two tubercles for the fore and aft sepals, then two for the lateral sepals; the four petals originate simultaneously; the two short stamens arise opposite the lateral sepals, the two other staminal tubercles are subsequently developed at a higher level than the preceding and decussate with them; these two after a time become notched, the notch gradually deepens and ultimately forms two distinct stamens. As a rule Crucifers have in the adult condition bractless flowers; a few species have bracts normally; and they sometimes occur as abnormalities.

**Distribution.**—This large Order is very natural, and, as usually happens in such cases, the genera are very difficult to define. The species are most abundant in temperate and cold climates, and seldom found otherwise than on mountains in the tropics.

**Qualities and Uses.**—The general character is antiscorbutic, the watery juice being often pungent and occasionally acrid. The seeds yield oil, which is contained in their cotyledons. By cultivation the acrid juices become milder, and the structures are easily made very succulent, from abnormal development of parenchyma. Under these conditions they become valuable esculents, either in their roots, as the Turnip (*Brassica Rapa*), their stem and leaf-stalks, as Sea-kale (*Crambe maritima*), their stem, leaves, or undeveloped inflorescence, as Kohl-rabi, Cabbages, Greens, Kales, &c. in all their varieties, and Cauliflower and Broccoli, all apparently derived from *Brassica oleracea* by cultivation. *Brassica Napus*, Rape or Colza, is most valuable on account of the oil in its seeds, and its oil-cake as food for cattle. The Swede Turnip is supposed to be a hybrid between *B. campestris* and *B. Rapa* or *Napus*. Radishes (*Raphanus sativus*), Horse-radish (*Armoracia rusticana*), are cultivated on account of their pungency, as are also the herb and, still more, the seeds of the Mustards, *Sinapis alba* and *nigra*, the latter of which yields the proper table-mustard seed. Water-cress (*Nasturtium officinale*) and Garden-cress (*Lepidium sativum*) are pungent salad-plants. *Isatis tinctoria* and a Chinese species, *I. indigotica*, yield a blue dye from their silicles.

Many of the Cruciferæ are remarkable for containing sulphur compounds, both in the seeds and in the herbage, whence the disagreeable smell of water in which they have been boiled, or even of the bruised fresh plant of some, as *Erysimum Alliaria*. Oil of Mustard, obtained by macerating the seeds of Black Mustard in water and distilling, is violently acrid. Most of the genera cited in the list above are represented by common wild plants in this country, the rest are found in most gardens; *Matthiola* is the Stock, *Cheiranthus Cheiri* the Wallflower, &c.

## ORDER XV. CAPPARIDACEÆ. THE CAPER ORDER.

*Class.* Rhœades, *Endl.* *All.* Cistales, *Lindl.* *Coh.* Parietales, *Benth. et Hook.*

372. *Diagnosis.*—Herbs, shrubs, or rarely trees, with alternate simple or lobed exstipulate leaves; cruciform flowers; stamens numerous, or, if 6, not tetradynamous, on a disk, or with an internode separating them from the corolla, and a 1-celled pod or berry with 2 or more parietal placentas; seeds reniform, exalbuminous.

ILLUSTRATIVE GENERA.

| Tribe 1. CLEOMEÆ. *Fruit capsular.* | Tribe 2. CAPPAREÆ. *Fruit baccate.* |
|---|---|
| Cleome, *DC.* | Cadaba, *Forsk.* |
| Polanisia, *Raf.* | Capparis, *L.* |

**Affinities.**—This Order is closely related to the Cruciferæ, both in structure and properties, being distinguished chiefly by the mostly indefinite stamens, which when only six in number are very rarely tetradynamous, and by the stipitate ovary. The parietal placentas and the disk ally them to the Resedaceæ, which likewise have kidney-shaped exalbuminous seeds; there is a more distant affinity to the Bixaceæ, which have albuminous seeds. The development of the internodes between the circles of floral organs is a striking character in various Capparidaceæ: in *Cleome* and *Capparis* the receptacle has rather a discoid development below the stamens, the ovary being stalked; in *Gynandropsis* and *Cadaba* there is a stalk-like prolongation of the receptacle between the corolla and stamens and between the stamens and the ovary. This structure connects the plants in some degree with Passifloraceæ. In other genera the receptacle is developed into a more or less fleshy or glandular disk. In *Physostemon* the stamens are curious, the two or four posterior ones having the filaments inflated or swollen below the anthers.

**Distribution.**—The species are somewhat numerous in the tropical and subtropical regions of the world, especially in Africa.

**Qualities and Uses.**—There is great agreement with the Cruciferæ; but in some cases the pungent principles are dangerous. The Capers used as pickles are the flower-buds of various species of *Capparis* (*C. spinosa*, *Fontanesii*, *rupestris*, and *ægyptiaca*). The root of *Cratæva gynandra*, the Garlic Pear, is said to be very acrid and to blister like Cantharides. *C. excelsa* is a large tree in Madagascar. The *Polanisia icosandra* of the United States is used as a vermifuge; and the root of *Cadaba indica* is said to be aperient and anthelmintic. Many species have been introduced into our gardens: a few bear the open air in sheltered places.

## ORDER XVI. RESEDACEÆ. THE MIGNONETTE ORDER.

*Class.* Rhœades, *Endl.* *All.* Cistales, *Lindl.* *Coh.* Parietales, *Benth. et Hook.*

373. *Diagnosis.*—Herbs with unsymmetrical 4–7-merous small flowers, commonly with a fleshy one-sided hypogynous disk between the petals and the (3–40) stamens, which it supports. Calyx open in the bud. Pod 3- or 6-lobed, 3- or 6-horned, 1-celled with 3 or 6 parietal placentas, opening at the top before the exalbuminous reniform seeds are ripe.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Reseda, *L.* | Oligomeris, *Cambass.* |

These plants agree in many respects with the Capparidaceæ, as in the presence of a disk supporting the stamens, and the reniform seeds. By Müller they are placed between Capparids and Crucifers, which seems the most appropriate place for them. There is a more distant relation to the Papaveraceæ, from which, however, they are always distinguished by their exalbuminous seeds. Moringaceæ have many points in common, but differ in habit, foliage, straight embryo, and monadelphous stamens. The opening of the ovary before the seeds are ripe is worthy of note as an uncommon phenomenon; it is well seen in the Garden Mignonnette (*Reseda odorata*). *Oligomeris* is remarkable for the reduction of the parts of the flower, having but 2 petals and 3 stamens, and the disk is likewise absent.

**Distribution.**—A small order. Most of the kinds are European; but a few occur in India, South Africa, and in California.

**Qualities and Uses.**—The best-known plant of the Order is *Reseda odorata*, so much valued for its perfume and hardy character. *Reseda luteola*, a native weed, commonly called Weld, yields a yellow dye. Some of the species are acrid.

## ORDER XVII. BIXACEÆ OR FLACOURTIACEÆ.
### THE ANNATTO ORDER.

*Class.* Parietales, *Endl.* *All.* Violales, *Lindl.* *Coh.* Parietales, *Benth. et Hook.*

374. *Diagnosis.*—Shrubs or small trees with alternate exstipulate leaves, usually entire and leathery, often dotted; regular hermaphrodite or unisexual flowers; sepals 4–7, slightly coherent below; petals as many and distinct, or absent; stamens hypogynous, generally indefinite; ovary sessile, or slightly stalked, 1- or rarely more-celled, with 2 or more parietal placentas; ovules curved; seeds numerous, with a straight embryo in the axis of fleshy albumen; cotyledons broad; radicle next the hilum.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Bixa, *L.* | Flacourtia, *Commers.* |
| Oncoba, *Forsk.* | Erythrospermum, *Lam.* |

Related to the Samydaceæ, but distinguished by their hypogynous stamens, and to the Passifloraceæ, but destitute of a coronet. From Capparids they differ in their albuminous seeds; from Cistaceæ in their straight ovules. Bentham and Hooker refer the small group Pangiaceæ (*see post*) here.

The species are not very numerous, and are mostly natives of the hottest regions of the globe; some of the plants are bitter and astringent; the pulpy fruits of *Oncoba*, of *Flacourtia Ramontchi*, *sapida*, and *sepiaria* are edible. *Bixa Orellana* yields the substance called Annatto, used for colouring cheeses and as a dye; it is derived from a pulp surrounding the seeds.

## ORDER XVIII. CISTACEÆ. ROCK ROSES.

*Class.* Parietales, *Endl.* *All.* Cistales, *Lindl.* *Coh.* Parietales, *Benth. et Hook.*

375. *Diagnosis.*—Low shrubs or herbs with regular hermaphrodite flowers, persistent calyx, distinct hypogynous, mostly indefinite stamens; pod 1-celled, 3–5-valved, with as many parietal placentas; ovules straight; seeds albuminous; embryo curved or spiral, with the radicle remote from the hilum.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Cistus, *Tournef.* | Helianthemum, *Tournef.* |

**Affinities, &c.**—Nearly related to Violaceæ, Bixaceæ, and Droseraceæ, but distinguished by the form and direction of the embryo, from the Hypericaceæ by the structure of the fruit and the absence of dots on the leaves, and from Linaceæ by the fruit; they also approach Papaveraceæ by *Dendromecon*: and Lindley considers that there is some connexion with Capparidaceæ and Cruciferæ; but the 4-merous plan and exalbuminous seeds of those Orders remove them widely. Some of the Helianthema have dimorphic flowers.

The Cistaceæ are most abundant in South Europe and North Africa, but occur in other parts of the globe. The gum-resin called Ladanum is obtained from *Cistus creticus, ladaniferus, Ledon,* and others; and the plants generally are regarded as resinous and balsamic. Many species are cultivated for their beautiful but fugacious flowers.

*Helianthemum vulgare*, a native plant, is remarkable for the irritability of the stamens in the newly opened flowers.

## ORDER XIX. DROSERACEÆ. SUN-DEWS.

*Class.* Parietales, *Endl.* *All.* Berberales, *Lindl.* *Coh.* Rosales, *Benth. et Hook.*

376. *Diagnosis.*—Bog-herbs, mostly glandular-haired, with regular hypogynous flowers, 5-merous and persistent (withering) calyx, corolla, and stamens; the anthers fixed by the middle, extrorse; ovary free; ovules numerous, inverted; pod 1-celled, with twice as many separate styles and stigmas as there are parietal placentas; the embryo minute, at the base of fleshy albumen.

### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Drosera, *L.* | Aldrovanda, *Monti.* | Dionæa, *Ellis.* |

The interesting but not very numerous plants of this Order are remarkable for the circinate curvature of their flower-stalks, which, together with the absence of stipules, the extrorse anthers, divided styles, &c., separates them from the Violaceæ, which they approach; they are connected with Hypericaceæ by *Parnassia*, and have some affinity to Cistaceæ and Turneraceæ. Bentham and Hooker place them near the Saxifrages, These plants are found in bogs or marshes in most parts of the globe. excepting the Arctic regions. Their double stigmas are curious; but their most interesting characters reside in the leaves, which in *Drosera* (Sun-dews) are covered with beautiful glandular hairs: three species occur in this country. *Aldrovanda vesiculosa*, a native of South Europe, has curious whorled cellular spoon-shaped leaves; while *Dionæa muscipula*, the Venus's Fly-trap of the North-American bogs (occasionally cultivated in stoves here), is well known for the remarkable irritability of the lamina of the leaf, the two lobes of which close upon any object touching the upper face. The Droseraceæ are said to be acrid.

## ORDER XX. VIOLACEÆ. THE VIOLET ORDER.

*Class.* Parietales, *Endl.* *All.* Violales, *Lindl.* *Coh.* Parietales, *Benth. et Hook.*

377. *Diagnosis.*—Herbs or shrubs; leaves alternate, usually stipulate; flowers regular or irregular, hermaphrodite, with a somewhat irregular 1-spurred corolla of 5 petals; stamens 5, hypogynous, with adnate introrse anthers connivent over the pistil, connective of the anther usually prolonged; style and stigma single; pod 1-celled; 3-valved, with 3 parietal placentas in the middle of the valves; seeds albuminous; embryo straight.

### *Character.*

*Calyx*: *sepals* 5, persistent, usually elongated at the back, imbricated in æstivation.

*Corolla*: *petals* 5, hypogynous, equal or unequal, one usually spurred, withering-persistent; obliquely convolute in æstivation.

*Stamens* 5, alternate with the petals, or occasionally opposite, inserted on an hypogynous disk, often unequal; anthers 2-celled, introrse, separate or cohering, and lying upon the pistil; the filament or connective prolonged beyond the lobes of the anthers, in the irregular flowers two of the filaments are spurred at the base.

*Ovary* compound, 1-celled, with numerous ovules on 3 parietal placentas opposite the 3 outer sepals, or rarely 1-ovuled; *ovules* anatropous; *style* single, mostly declinate; *stigma* capitate, oblique, hooded.

*Fruit*: a capsule bursting into 3 valves, with the placentas up the middle; *seeds* mostly numerous; *embryo* straight in the axis of fleshy albumen.

### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Viola, *L.* | Papayrola, *Aubl.* | Alsodeia, *Thouars.* |

**Affinities.**—By the irregular flowers and appendaged anthers we readily distinguish most of the Violaceæ from the Droseraceæ, Cistaceæ, and Sauvagesiaceæ; and in *Alsodeia*, where the corolla is regular, the simple style and capitate stigma are still available; and several other important differences exist, such as:—the definite number of stamens and straight embryo, unlike that of the Cistaceæ; different vernation and stipulate condition of the leaves, unlike Droseraceæ; while Sauvagesiaceæ, besides having the anthers unappendaged, have either numerous stamens, or, if five, they are opposite to the petals and alternate with five scales; moreover the capsule bursts septicidally, so that the placentas are at the edges of the valves. Violaceæ are related more distantly to Passifloraceæ. In the native species of the genus *Viola*, it is not uncommon to find apetalous flowers, especially in the autumn.

**Distribution.**—An Order consisting of a few genera, some, such as *Viola* and *Alsodeia*, rich in species, the greater number with but few. The irregular Violaceæ belong chiefly to Europe, North Asia, and North America, where they are generally small herbs, and to South America, where they are mostly shrubby; the regular genera, *Alsodeia* &c., belong to South America, Africa, and Malacca.

**Qualities and Uses.**—The Order is characterized in general by emetic properties, which are especially developed in the South-American *Ionidia*; *I. parviflorum*, *I. Poaya*, *I. Itubu*, are used there instead of Ipecacuanha, and the last was formerly supposed to be the true Ipecacuanha-plant. *Viola canina*, the common Dog-violet of our hedges, is said to be beneficial in skin-diseases; and the same properties are attributed to *Anchietia salutaris* in Brazil, where it is also used as a purgative. The roots of the Sweet Violet, *V. odorata*, are emetic and purgative; its seeds are also purgative. *V. tricolor* is the Pansy or Heart's-ease; its leaves have been supposed to contain hydrocyanic acid, since they smell like peach-blossom when bruised.

The SAUVAGESIACEÆ form a small group sometimes separated from Violaceæ on account of the characters mentioned above. They are related to the Hypericaceæ through *Parnassia*.

## ORDER XXI. FRANKENIACEÆ.

*Class.* Parietales, *Endl.* *All.* Violales, *Lindl.* *Coh.* Caryophyllineæ, *Benth. et Hook.*

378. This small and unimportant Order bears very close affinity to the tribe Sileneæ of the Order Caryophyllaceæ in the floral envelopes and stamens; but its placentas are parietal, and the embryo is straight, which causes it to approach Violaceæ, and especially Sauvagesiaceæ, from which, however, it differs in their united sepals and extrorse anthers. Most of the plants are found in South Europe and North Africa; but a few species are scattered in other parts of the world. They are said to be mucilaginous and aromatic.

### ILLUSTRATIVE GENUS.

Frankenia, *L.*

## ORDER XXII. TAMARICACEÆ. THE TAMARISK ORDER.

*Class.* Guttiferæ, *Endl.* *All.* Violales, *Lindl.* *Coh.* Caryophyllinæ, *Benth. et Hook.*

379. *Diagnosis.*—Shrubs or herbs of fastigiate growth, with alternate scale-like leaves, usually pitted; flowers in close spikes or racemes; calyx 4–5-parted, persistent; petals distinct, adherent to the calyx, withering; both imbricated in æstivation; stamens hypogynous, equalling the petals or twice as many, distinct or coherent; ovary superior, ovules numerous, ascending; capsule 3-valved, 1-celled, with 3 placentas either at the base

or 1 in the middle of each valve; seeds comose, without albumen; embryo straight; radicle inferior.

### ILLUSTRATIVE GENERA.

Tamarix, *L.* | Myricaria, *Desv.*

**Affinities.**—Endlicher looked upon this Order as intermediate between Hypericaceæ (through Reaumuriaceæ) and Lythraceæ, while Lindley thinks they stand rather between Violaceæ and Crassulaceæ, and De Candolle placed it near Portulacaceæ, as also do Bentham and Hooker. From all the above, however, they differ in the nature of their seeds.

**Distribution.**—A group consisting of two genera, one with several, the other with very few species. The plants are natives of the northern hemisphere of the Old World, growing chiefly by the sea-shore, or on the margins of rivers or lakes.

**Qualities and Uses.**—The bark is bitter and astringent; and those kinds growing near the sea yield abundance of soda when burnt. *Tamarix mannifera* yields the Manna of Mount Sinai, a kind of mucilaginous sugar, said to be exuded in consequence of the attacks of a Coccus-insect. Several species are attacked by gall-insects, and the galls of *T. indica, dioica, Furas,* and *orientalis* are used in medicine and for dyeing. *Tamarix gallica* flourishes well near the sea on our coasts, and is an ornamental shrub. *Myricaria germanica* is a handsome shrub in our gardens.

## ORDER XXIII. CARYOPHYLLACEÆ. THE PINK ORDER.

*Class.* Caryophyllaceæ, *Endl.* *All.* Silenales, *Lindl.* *Coh.* Caryophyllinæ, *Benth. et Hook.*

380. *Diagnosis.*—Herbs with opposite entire leaves; stems swollen at the joints; flowers symmetrical, 4–5-merous, with or without petals; stamens distinct, not more than twice as many as the sepals, hypogynous or perigynous; styles 2–5; seeds attached to the base or to the central placenta of the 1-celled (rarely 3–5-celled) capsule; embryo curved round the mealy albumen.

### *Character.*

*Calyx*: *sepals* 4 or 5, persistent, distinct or coherent into a tube.

*Corolla*: *petals* 4 or 5, clawed, often deeply bifid, sometimes wanting, mostly separated by a short internode from the calyx.

*Stamens* twice as many as the petals, or equal to and opposite to the sepals, sometimes fewer, inserted with the petals; *filaments* awl-shaped, sometimes coherent; *anthers* innate.

*Ovary* sessile, or raised with the corolla and stamens on a short stalk above the calyx, 1-celled, with a central placenta or with 2–5 dissepiments extending to the centre; *ovules* few or numerous; *stigmas* 2–5, filiform, resembling the styles, but papillose down the inner side.

*Fruit* capsular, 1-celled, with a central placenta, 2–5-valved, or splitting into 4–10 teeth above (fig. 350), or 2–5-celled, loculicidally dehiscent, with the placentas adhering to the septa; *seeds* mostly indefinite; the *embryo* mostly curved round the albumen (fig. 351), rarely straight or spiral, with little albumen; radicle next the hilum.

Fig. 350.

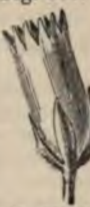


Fig. 351.

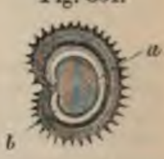


Fig. 350. Capsule of *Cerastium*, burst.
Fig. 351. Section of seed of *Lychnis*: *a*, endosperm; *b*, embryo.

ILLUSTRATIVE GENERA.

Tribe 1. ALSINEÆ. *Sepals distinct.*
- Sagina, *L.*
- Alsine, *Wahlenb.*
- Arenaria, *L.*
- Stellaria, *L.*
- Cerastium, *L.*

Tribe 2. SILENEÆ. *Sepals cohering into a tube.*
- Dianthus, *L.*
- Saponaria, *L.*
- Silene, *L.*
- Lychnis, *L.*

**Affinities.**—The opposite entire leaves springing from thickened nodes, definite stamens, and the character of the placenta and seeds serve to distinguish the great majority of this well-marked Order. The nearest relations of the Caryophyllaceæ, as here defined, are unquestionably the Illecebraceæ and Portulacaceæ, which we separate more for the sake of convenience of distinction than on account of natural diversity, since in both those Orders there is a variation between the hypogynous and perigynous conditions. The Illecebraceæ may be distinguished by their scarious stipules and utricular fruit, and the Portulacaceæ by the 2-leaved calyx and by the stamens when equal to the sepals being alternate, or opposite to the petals, since it seems more convenient to keep the *Molluginea* with Portulacaceæ if they are divided. The apetalous forms, and the alliance with the Orders just named, connect this Order with the Amarantaceæ and Chenopodiaceæ and several other families all characterized by a curved embryo surrounding a floury albumen.

The placentation of the Caryophyllaceæ is regarded by some authors as forming one of the exceptions to the marginal type, the free central column of mature ovaries being regarded as a product of the receptacle, independent of the carpels. But the dissepiments exist in the early stages of development, and are torn away during the expansion of the ovary: hence there is no necessity to assume the independent origin of the placentas. Monstrous blossoms of plants of this Order do not decide the question, since these have been found with really independent growth of the ovules from the base of the ovary, and with ovules developed upon the margins of the carpels.

**Distribution.**—An Order consisting of several genera and a large number of species, for the most part natives of temperate and cold climates, extending to the Arctic regions and to almost the extreme limit attained by flowering plants on mountains.

**Qualities and Uses.**—The plants of this Order are generally devoid of active properties—some of them containing more or less of a deleterious principle, called *Saponine*, as *Saponaria*, *Agrostemma*, *Silene*, &c.; and *Gypsophila Struthium*, the Egyptian Soap-root, derives its name from its saponaceous properties; this substance is generally most abundant in the roots. The genus *Dianthus*, or Pink, is remarkable for the beauty of its flowers; *D. barbatus* is the Sweet-William; *D. plumarius* is the parent of the varieties of Garden Pink; *D. Caryophyllus* (the Clove-Pink), of the Carnation and its varieties. *Lychnis* and *Silene* also afford handsome garden plants. A large proportion of the plants of this Order are insignificant weeds; one of them, Spurrey (*Spergula arvensis*), is sometimes grown as an agricultural crop on poor soils, for feeding Sheep.

## ORDER XXIV. MALVACEÆ. THE MALLOW ORDER.

*Class.* Columniferæ, *Endl.* *All.* Malvales, *Lindl.* *Coh.* Malvales, *Benth. et Hook.*

381. *Diagnosis.*—Herbs or shrubs with alternate stipulate leaves often covered with soft down and regular flowers; calyx valvate, and corolla convolute in æstivation; stamens numerous, monadelphous in a tube which is adherent below to the short claws of the petals; anthers 1-celled.

### *Character.*

*Calyx*: *sepals* 5, rarely 3 or 4, more or less united below, valvate in the bud, often surrounded by an epicalyx (§ 164).

*Corolla*: *petals* equal in number to the sepals, hypogynous, contorted in æstivation, free or adherent to the tube of the stamens.

*Stamens* indefinite, monadelphous, hypogynous, all perfect; *anthers* 1-celled, kidney-shaped, bursting across.

*Ovary*: *carpels* several, each forming a cell around a central axis, either coherent into a multilocular compound ovary, or distinct; *ovules* definite or indefinite, on the ventral suture; *styles* equal in number to the carpels or twice as many; coherent or distinct; *stigmas* various.

*Fruit*: a several-celled capsule, or a collection of separating indehiscent cocci or of follicles, the carpels 1- or many-seeded; *seeds* with little or no albumen, *embryo* curved, cotyledons much twisted, oily, testa sometimes hairy.

### Illustrative Genera.

Tribe 1. Malveæ. *Herbs or undershrubs. Staminal column antheriferous to the top; styles as numerous as the cells of the ovary; ripe carpels seceding from the columella.*

Malope, *L.*
Althæa, *L.*
Malva, *L.*
Sida, *L.*

Tribe 2. Ureneæ. *Herbs. Staminal column destitute of anthers at the top; styles twice as many as the cells of the ovary; fruit as in* Tribe 1.

Pavonia, *L.*

Tribe 3. Hibisceæ. *Herbs or undershrubs. Styles as many as the carpels; fruit syncarpous, capsular.*

Hibiscus, *L.*
Gossypium, *L.*

Tribe 4. Bombaceæ. *Trees or shrubs. Staminal column divided into 5 or more divisions, each with one or more anthers; styles confluent or equal to the carpels; fruit syncarpous, dehiscent or indehiscent.*

Adansonia, *L.*
Bombax, *L.*

**Affinities.**—The "compound" stamens of these plants appear first in the form of five little tubercles, the primordial stamens; from the sides of these are subsequently developed others. The anthers are bilocular in the first instance, but become 1-celled by the obliteration of the partitions. Malvaceæ are closely allied to Byttneriaceæ, Sterculiaceæ, and Tiliaceæ, especially to the first two, by the general structure and the æstivation of the calyx, but are distinguished by their 1-celled anthers from all three; to the Geraniaceæ they are related by the monadelphous stamens, twisted æstivation of the corolla, and the occasional separation of the carpels from a central axis in the ripe fruit; with Chlænaceæ there is a connexion through the epicalyx or calycine involucre and the monadelphous stamens; and some points of structure, but especially the properties, resemble those of Linaceæ: from Camelliaceæ, which have the stamens more or less coherent, they may be distinguished by the valvate calyx. *Malope* presents a curious condition of the carpels, which are numerous and distinct, resembling those of a Ranunculaceous plant. The Bombaceous subdivision is referred here on account of the 1-celled anthers. The trunks of some of the trees in this group attain enormous age and dimensions, as in the *Adansonia* or Baobab, and the *Bombax*, the latter of which produce great projecting buttresses from their stems. The calyx in this subdivision is tough and leathery; and the pollen is generally smooth, not spiny, as in the rest of the family. The hairy seeds of this subdivision recall those of *Gossypium*.

**Distribution.**—A large order, with several genera and very numerous species; the latter are most abundant in the tropics, diminishing gradually in the temperate regions, and absent from the frigid zone.

**Qualities and Uses.**—The ordinary properties of this Order depend on the abundance of a bland mucilage, especially in the roots, as in the Marsh-mallow (the French *Guimauve*) (*Althæa officinalis*), the flower of the Hollyhock (*Althæa rosea*), the common Mallow (*Malva sylvestris*), &c. The leaves of the Hollyhock yield a blue dye like indigo. But the most important qualities of these plants depend upon their tissues, namely the fibrous liber of their stems, which in some cases furnishes large quantities of hemp-like fibre to commerce, as the *Hibiscus cannabinus* (Sun-hemp), *H. arboreus*, various species of *Sida*, &c., and the hairs of the seeds of *Gossypium*, constituting Cotton. Four distinct species of Cotton are supposed to exist, viz.:—*G. herbaceum*, the ordinary Indian Cotton-plant *G. arboreum*, the Indian Tree-cotton; *G. barbadense*, to which the North-American Cottons belong, and the Bourbon cotton of India; and *G. peruvianum* or *acuminatum*, Pernambuco or Brazil cotton. The seeds of *Gossypium* contain a large quantity of almost colourless oil, together with a brown resinous substance contained in special reservoirs, which colours the expressed oil. The hairs of the seeds of the Silk-cotton trees (*Bombax*) cannot be spun like cotton, but are used for stuffing cushions &c. The Durian (*Durio zibethinus*) has an aromatic edible fruit. The fruit of the Baobab (*Adansonia*) has an agreeable acid juice. Most of the Malvaceæ have handsome flowers, and many are cultivated in our gardens and stoves.

## ORDER XXV. BYTTNERIACEÆ. THE CHOCOLATE ORDER.

*Class.* Columniferæ, *Endl.* *All.* Malvales, *Lindl.* *Coh.* Malvales, *Benth. et Hook.*

382. *Diagnosis.*—Trees or shrubs, occasionally climbers, with alternate simple leaves and mostly with deciduous stipules; calyx 4–5-lobed, valvate; corolla absent, or of 5 variable petals; stamens hypogynous, definite, and opposite to the petals or twice as many, half sterile (staminodes), almost always inserted into a cup or tube: anthers 2-celled, introrse; ovary sessile or stalked, of 4–10 carpels round a central column; embryo generally in a small quantity of albumen, cotyledons plaited.

### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Byttneria, *Lœfl.* | Scaphopetalum, *Mast.* | Melhania, *Forsk.* |
| Theobroma, *L.* | Dombeya, *Cav.* | |

**Affinities.**—This Order is very near Sterculiaceæ, with which, indeed, it is combined by Bentham and Hooker, but is distinguished by the introrse anthers, some of which are usually sterile; the same organs, being 2-celled, afford a distinction from Malvaceæ, to which they at the same time approach; the monadelphous stamens and the absence of a disk remove them from Tiliaceæ. Lindley thinks that the frequent absence of the corolla and the occurrence of sterile stamens indicate a relationship to Euphorbiaceæ. The staminodes represent certain portions of the "compound" stamen not antheriferous (see under Malvaceæ). Sometimes the staminode forms the terminal, or at other times a lateral lobe of the primary stamens, which in these cases may be compared to a digitate leaf. The staminode in some cases seems to serve the purpose of collecting and retaining the pollen.

**Distribution.**—A small order whose members are natives chiefly of the tropics of both hemispheres.

**Qualities and Uses.**—These plants generally resemble Malvaceæ in properties. *Abroma* and *Dombeya* furnish materials for cordage; *Guazuma ulmifolia* (Brazil) has an agreeable, sweet, mucilaginous fruit. The most interesting member of the Order, however, is the *Theobroma Cacao*, from the fruits and seeds (Cacao beans) of which chocolate and "cocoa" are prepared. A spirit is also distilled from the pulp of the fruit. Species of many of the genera have been introduced as greenhouse shrubs, but most of them are unattractive. Some of the species of *Dombeya* are very ornamental.

## ORDER XXVI. STERCULIACEÆ. THE STERCULIA ORDER.

*Class.* Columniferæ, *Endl.* *All.* Malvales, *Lindl.* *Coh.* Malvales, *Benth. et Hook.*

383. *Diagnosis.*—Trees or shrubs with alternate simple or compound leaves and free deciduous stipules; flowers regular or irregular, frequently unisexual by abortion; calyx and corolla resembling those of Malvaceæ or petals absent; stamens monadelphous or polyadelphous; anthers 2-celled and extrorse; carpels 5, rarely 3, distinct or coherent, often pedicellate; seeds very variable.

### ILLUSTRATIVE GENERA.

Tribe 1. STERCULIEÆ. *Leaves simple or palmate; flowers apetalous and unisexual by abortion.*

Heritieria, *Ait.*
Sterculia, *L.*
Cola, *Schott.*

Tribe 2. HELICTEREÆ. *Leaves simple; flowers perfect; petals deciduous; staminodes small.*

Helicteres, *L.*

Tribe 3. FREMONTIEÆ. *Flowers hermaphrodite; stamens conjoined; anthers 5; staminodes wanting.*

Fremontia, *Hook.*
Cheirostemon, *L.*

Tribe 4. HERMANNIEÆ. *Flowers hermaphrodite; petals persistent, twisted in æstivation; stamens distinct; staminodes wanting.*

Hermannia, *L.*
Waltheria, *L.*

**Affinities.**—The perfect, 2-celled, extrorse stamens separate the plants of this Order from the Malvaceæ and Byttneriaceæ, the monadelphous condition from the Tiliaceæ. The *Helictereæ* are midway between *Bombaceæ* and *Sterculieæ*, and the *Sterculieæ* form the transition to the Byttneriaceæ.

Many plants of this Order are interesting in structural respects. *Delabechea* (Australia), *Brachychiton*, and others have a trunk swollen midway between the ground and the crown of the tree, giving the appearance of a huge flask or bottle. *Helicteres* is so called from its twisted follicles; the pods of some *Sterculieæ* open out like leathery leaves with the ripe seeds on their margins. The species of *Sterculia* and *Cola* are remarkable for the variable condition of their seed, some having albumen, others not; the direction of the radicle with reference to the hilum is also different in different species. *Cola* has often three or four cotyledons, or perhaps two, deeply divided.

**Distribution.**—An Order not very numerous in species, which latter are natives of the tropics. The *Sterculieæ* chiefly in India and Africa.

**Qualities and Uses.**—Mucilaginous. *Sterculia Tragacantha* yields the gum Tragacanth of Sierra Leone, *S. urens* a similar gum; the seeds of all the species are oily, like those of Malvaceæ; the same properties are generally diffused. *Sterculia guttata* and *villosa* yield fibres fit for cordage and woven fabrics. *Cola acuminata* furnishes the Cola nuts, greatly esteemed by the negroes for their bitter properties. *Cheirostemon platanoides*, the Hand-plant of Mexico, has a remarkable-looking flower: the tube of the monadelphous stamens is split above and spread out, so that the anthers resemble five fingers or claws, while the curved style looks like a thumb. This and various other plants of the Order have been introduced as stove-shrubs.

## ORDER XXVII. TILIACEÆ. THE LIME OR LINDEN ORDER.

*Class.* Columniferæ, *Endl.* *All.* Malvales, *Lindl.* *Coh.* Malvales, *Benth. et Hook.*

384. *Diagnosis.*—Trees (rarely herbs) with alternate usually stipulate leaves; flowers regular, hermaphrodite; calyx valvate; petals imbricated in æstivation; sepals deciduous; stamens usually polyadelphous; anthers 2-celled.

### *Character.*

*Calyx* of 4–5 distinct or coherent sepals, valvate in æstivation.

*Corolla* of 4–5 distinct petals, imbricated or wanting.

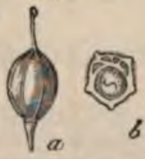
*Stamens* mostly numerous, hypogynous, distinct or united in parcels, sometimes surrounded by the enlarged border of the disk beneath the ovary; *anthers* 2-celled, dehiscing longitudinally or by pores.

*Ovary* single, many-celled, composed of 2–10 carpels (sometimes disunited) with the placentas in the inner angle (axile); *ovules* few or numerous; style 1, stigmas = the carpels.

*Fruit* dry or succulent, sometimes samaroid; many-celled or 1-celled by abortion (fig. 352).

*Embryo* erect, in the axis of fleshy albumen, with flat cotyledons and radicle next the hilum.

Fig. 352.



Fruit of *Tilia*: *a*, entire; *b*, cross section, showing 1 fertile and 4 abortive cells.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Luhea, *Willd.* | Triumfetta, *Plum.* | Grewia, *Juss.* |
| Corchorus, *L.* | Tilia, *L.* | Elæocarpus, *L.* |

**Affinities.**—The distinct or polyadelphous stamens, the 2-celled anthers, and the disk separate these plants from their near allies, the Malvaceæ, Byttneriaceæ, and Sterculiaceæ. From Camelliaceæ they differ in the æstivation of the calyx, and from Bixaceæ in the structure of the fruit. Various remarkable peculiarities of structure occur in the genera. Some species of *Apeiba* are said to have 24 cells in the fruit; *Diplophractum* has parietal placentas with spurious dissepiments in the fruit. The polyadelphous stamens of *Luhea*, and of the American species of *Tilia*, which stand in bundles before the petals, are supposed to be instances of *chorisis* (§ 149). Limes are peculiar in the adhesion of the flower-stalk to the bract. *Grewia* has glandular petals; *Elæocarpus* has them fringed, in some species they are absent.

**Distribution.**—There are between three and four hundred species, pertaining to thirty-five or forty genera. The Limes or Lindens (*Tilia*) are trees of the northern parts of both hemispheres; but the rest of the Order are chiefly tropical. *Triumfettas* are tropical weeds with bur-like fruits.

**Qualities and Uses.**—The general properties are the same as those of the allied Orders—mucilaginous juices and fibrous bark. Many are valuable timber-trees, and some yield edible fruits. The fibrous liber of the European *Tiliæ* furnishes the well-known Russian "bast" or "bass;" various species of *Corchorus* furnish fibres in India, especially *C. capsularis*, which affords "Jute," a fibre very extensively substituted for hemp; *C. olitorius* is used as a pot-herb. The berries of *Grewia sapida, asiatica*, and others are pleasantly acid, and are used in making sherbet; and the berries of some kinds of *Corchorus* and of *Elæocarpus* are eaten. Various species of *Luhea* (Brazil) and *Grewia* (East Indies) furnish valuable timber. The Lime-trees of Europe (*Tilia europæa, grandifolia*, and *parvifolia*) are valued not only for their *bast*, but for their beauty, their white even wood, and the fragrance of their blossoms. Many of the tropical species, such as *Sparmannia africana, Glyphæa grewioides*, have been introduced as stove-shrubs. *Honckenya ficifolia* has large violet flowers.

## ORDER XXVIII. DIPTERACEÆ.

*Class.* Guttiferæ, *Endl.* *All.* Guttiferales, *Lindl.* *Coh.* Guttiferales, *Benth. et Hook.*

385. *Diagnosis.*—Large trees abounding in resinous juice, with alternate strongly feather-ribbed leaves and large convolute deciduous stipules; flowers perfect, the calyx 5-lobed, lobes imbricate, unequal, persistent, afterwards enlarged like wings; petals 5, hypogynous; stamens hypogynous, indefinite, distinct, or slightly and irregularly polyadelphous; anthers subulate, produced above; ovary superior, 3-celled; fruit 1-celled by suppression, 1-seeded, and 3-valved or indehiscent, and surrounded by the enlarged calyx, forming a crown above it; seeds exalbuminous.

### ILLUSTRATIVE GENERA.

Dipterocarpus, *Gærtn.*
Dryobalanops, *Gærtn.*
Vateria, *L.*
Shorea, *Roxb.*
(Lophira, *Banks.*)

**Affinities.**—Tropical trees related to the preceding Orders in some respects, but in the imbricated calyx and in other particulars having more affinity to the Clusiaceæ, from which they differ in the æstivation of the corolla and in the presence of stipules. Their large deciduous stipules resemble those of *Magnolia*; but the most characteristic feature of the Order is the enlarged persistent calyx, which forms long winged lobes crowning the fruit. Some authors separate *Lophira* as the type of a distinct Order which is in some degree (as in its 1-celled ovary) different both from the Dipteraceæ and the Clusiaceæ, but may probably remain among the former.

**Distribution.**—This Order consists of ten or twelve genera, comprising upwards of a hundred species. These plants are large trees or rarely climbing shrubs of the forests of tropical Asia. *Lophira* belongs to Sierra Leone.

**Qualities and Uses.**—The juices yield a balsamic resin, of whch various kinds are imported. Sumatran hard Camphor is found in the form of concretions in fissures and cavities of the trunk of *Dryobalanops Camphora*; the Camphor-oil of Borneo and Sumatra is said to be the same substance in a fresher state. *Shorea robusta* yields the Dhoona or Dammar pitch, used for incense in India. *Vateria indica* affords the Piney resin or Piney Dammar of India, sometimes called Indian Copal or gum Animi, largely used for making varnish. *Dipterocarpus trinervis* and other species yield a balsam like Copaiba. *Lophira* is called the Scrubby Oak in Sierra Leone; its dry corky bark contains no resinous juice.

(CHLÆNACEÆ constitute a small Order, consisting at present of a few shrubs, natives of Madagascar; related to Malvaceæ in having monadelphous stamens and an epicalyx; but the calyx is imbricated in æstivation, like that of Camelliaceæ &c. Placed by Lindley near Oxalidaceæ, Balsaminaceæ, Linaceæ, and Geraniaceæ.)

## ORDER XXIX. TERNSTRŒMIACEÆ OR CAMELLIACEÆ. THE CAMELLIA ORDER.

*Class.* Guttiferæ, *Endl.* *All.* Guttiferales, *Lindl.* *Coh.* Guttiferales, *Benth. et Hook.*

386. *Diagnosis.*—Trees or shrubs, with alternate simple leaves and no stipules; flowers regular, polyandrous, hypogynous; sepals and petals both imbricated in æstivation; stamens more or less coherent (1-, 3-, or 5-adelphous) at the base, and adherent to the bases of the petals; anthers 2-celled; seeds few, sometimes arillate; albumen little or none; embryo straight or folded, with the cotyledons large and thin, oily.

### ILLUSTRATIVE GENERA.

Tribe 1. RHIZOBOLEÆ.
Caryocar, *L.*

Tribe 2. MARCGRAAVIEÆ.
Marcgraavia, *L.*

Tribe 3. TERNSTRŒMIEÆ.
Ternstrœmia, *L. f.*

Tribe 4. SAURAUJEÆ.
Sauraja, *Willd.*

Tribe 5. GORDONIEÆ.
Gordonia, *Ellis.*
Camellia, *Linn.*

Tribe 6. BONNETIEÆ.
Kielmeyera, *Mart.*

**Affinities, &c.**—Ternstrœmiads differ from Bixads in their many-celled ovary and want of stipules; from Dipterocarps in their calyx, which is not accrescent, their many-celled ovary, and watery (not resinous) juice. From *Tiliaceæ* they differ in their imbricate (not valvate) calyx; from Guttifers in their alternate leaves, usually perfect flowers, long style, curved embryo, &c. From Hypericads they differ in habit, foliage, and inflorescence. Through *Sauraja* they are connected with the Ericaceous genus *Clethra* and with Dilleniads. *Eurya* establishes a connexion with *Sapotaceæ*; but these latter plants have extrorse anthers. The tribe *Marcgraavieæ*, by some considered a distinct Order, comprises a few plants differing from the rest of the Order in their aggregate flowers, introrse, basifixed anthers, sessile stigmas, and specially in their very peculiar horn-like tubular bracts. The *Rhizoboleæ* are large trees, with opposite digitate leathery leaves, with an articulated stalk, and no stipules; sepals 5 or 6, more or less coherent, imbricated; petals 5–8, inserted with the numerous stamens on an hypogynous disk; stamens slightly coherent, in two circles, the inner shorter and often abortive; ovary superior, 4–5- or many-celled, with as many short styles and minute stigmas, each cell with 1 ovule attached in the axis; fruit of several combined indehiscent 1-seeded nuts, with a large exalbuminous seed chiefly consisting of an enormous radicle with the cotyledons lying in a groove. The large palmate leaves of *Caryocar* resemble those of *Æsculus*; but here the radicle, and not the cotyledons, forms the mass of the embryo.

**Distribution.**—The Ternstrœmiads constitute a rather large family distributed mainly in tropical America and Eastern Asia; very few are found in North America, and one species in the Canaries.

**Qualities and Uses.**—Some *Saurajas* possess emollient properties. *Gordonia* is astringent. Tea is the produce of *Thea chinensis*; black tea and green tea are produced by the same plant, the difference consisting in the time of picking and mode of preparation of the leaves. The stimulant properties of tea are due to the presence of a volatile oil and an astringent principle; the nutritive qualities to a nitrogenous substance called theine. The leaves also contain caseine, which, being insoluble in water, is not utilized by us; but it is stated that the Tibetans, after drinking the infusion, mix the leaves with fat and then eat them.

Assam tea is the produce of a species, *T. Assamica*, a native of the district whence its name is derived. *Camellia Sasanqua* is used with *Olea fragrans* to give flavour and perfume to Chinese tea; *C. oleifera* affords excellent salad-oil. *Freziera theoides* is made into tea in Panama. The Marcgraavias have diuretic properties. The Souari nuts of commerce are the separated fruit-lobes of *Caryocar butyrosum*, so called on account of the oil in the seeds. The timber of this tree is highly valued. Many of the plants of this Order are in cultivation on account of their handsome flowers, such as the *Camellia*, of which many hundred varieties are grown, *Gordonia*, *Stuartia*, &c.

## ORDER XXX. CLUSIACEÆ OR GUTTIFERÆ.

### THE GAMBOGE ORDER.

*Class.* Guttiferæ, *Endl.* *All.* Guttiferales, *Lindl.* *Coh.* Guttiferales, *Benth. et Hook.*

387. *Diagnosis.*—Trees or shrubs, occasionally parasitical, with resinous juice; opposite, coriaceous, exstipulate, entire leaves; flowers axillary or terminal, perfect or diclinous by abortion; sepals imbricated in 2 or more decussating pairs, usually persistent and petaloid; petals hypogynous, isomerous with the sepals, sometimes confounded with them; stamens

hypogynous, numerous, distinct, or in several parcels, rarely definite, filaments of various lengths; anthers adnate, not beaked, sometimes 1-celled, opening by a pore or transverse slit; disk fleshy, sometimes 5-lobed; ovary superior, 1- or many-celled; stigmas sessile, peltate, or radiate; ovules solitary or few on axile placentas; seeds frequently with an aril, without albumen.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Clusia, *L.* | Xanthochymus, *Roxb.* | Calophyllum, *L.* |
| Garcinia, *L.* | Cambogia, *L.* | |

**Affinities.**—This Order is related to the Hypericaceæ in many respects, but may be distinguished by the tree-like habit, the leathery leaves with articulated stalks, the tendency to a binary arrangement of the floral envelopes, the seeds usually solitary in the cells of the ovary, &c. The genera with 5-merous flowers, *Arrudea*, *Moronobæa*, &c., form a connecting link. The relationship to Ternstrœmiads has been alluded to under that family. The *Clusiæ* are described as parasitical, overgrowing other trees and killing them; perhaps, however, they are merely epiphytic, like *Ficus*.

**Distribution.**—The genera are about twenty-five in number, comprising some two hundred and fifty species, distributed throughout the tropics, chiefly in South America, but some in Africa.

**Qualities and Uses.**—An acrid juice, forming a yellow gum-resin, with purgative properties, is one of the most striking characteristics of this Order. The various kinds of Gamboge are the most familiar examples of this substance; but from which species they are derived appears to be doubtful. Ceylon gamboge is said to be derived from *Cambogia Gutta* (*Hebradendron Cambogioides*, Grah.); the Pipe-gamboge of Siam from *Garcinia cochin-chinensis*; Coorg gamboge is also from a *Garcinia*; *G. elliptica* furnishes the gamboge of Sylhet. The species of *Clusia* yield a useful resinous juice, as do those of *Calophyllum*, *C. Calaba* furnishing the East-Indian resin called Tacamahaca. *Pentadesma butyracea*, the Butter- or Tallow-tree of Sierra Leone, is so named from the yellow fatty substance which exudes from the cut fruit. Although the resinous juices are usually so active in their properties, the fruits of various Clusiaceæ are not only edible, but highly prized for their delicious flavour. The Mammee Apple, or Wild Apricot of South America, is the fruit of *Mammea africana*; the juice of the flowers is fermented and distilled, and the sap is made into a kind of wine. The celebrated Mangosteen is the fruit of *Garcinia Mangostana* (native of Malacca); other species of *Garcinia*, as *G. pedunculata*, *cornea*, &c., have edible fruits. *Clusia flava* is called the Wild Mango, or Monkey-apple, in Jamaica.

## ORDER XXXI. HYPERICACEÆ. THE ST. JOHN'S WORT ORDER.

*Class.* Guttiferæ, *Endl.* *All.* Guttiferales, *Lindl.* *Coh.* Guttiferales, *Benth. et Hook.*

388. *Diagnosis.*—Herbs or shrubs with opposite, entire, dotted leaves, without stipules; regular hermaphrodite flowers, the petals mostly oblique

or convoluted in the bud; the many or few stamens polyadelphous, sometimes with glands between them; capsule 1-celled, with 2–5 parietal placentas and as many styles, or 3–5-celled by union of the dissepiments in the centre; dehiscence septicidal; seeds numerous, exalbuminous.

### ILLUSTRATIVE GENERA.

Hypericum, *L.* | Parnassia, *L.* (aberrant form). | Vismia, *Velloz.*

**Affinities.**—This Order is not distantly removed from the Clusiaceæ; but the habit, the hermaphrodite flowers, usually distinct styles, the want of articulation of the peduncles and petioles, the numerous seeds, and the 5-merous floral envelopes generally afford distinctive marks. From Ternstrœmiads they differ in their cymose inflorescence and opposite leaves. The dark-coloured glands on the borders of the petals are very characteristic here, as also the polyadelphous stamens, which are sometimes regarded as instances of *chorisis* (§ 149), but which more probably are compound stamens. The genus *Parnassia* differs from the rest of the Order in its alternate leaves and the stigmas opposite the parietal placentas; but in some species of *Hypericum* the axile placentas become drawn apart during the ripening of the seed, and show their really marginal origin; and the glands on the petals of *Parnassia* are probably related to the bundles of stamens of *Hypericum*. *Parnassia* is regarded by some as referable to Droseraceæ; it forms a link connecting the present Order with Cistaceæ and, being sometimes perigynous, also with Saxifragaceæ, with which latter group, indeed, it is associated by Hooker.

**Distribution.**—There are a considerable number of species, distributed through 8 or 10 genera. The plants are generally dispersed throughout the temperate and warmer regions of the globe.

**Qualities and Uses.**—When a yellow juice resembling that of Clusiaceæ exists, it is more or less purgative, as in some American *Hyperica*, and still more in the species of *Vismia*, which yield a gum-resin like gamboge; that of *V. guianensis* (Mexico and Surinam) is known as American Gummi Gutta. In the European species of *Hypericum* the essential oil of the glands predominates over the yellow juice, and they are sometimes used as tonics and astringents. *H. Androsæmum* and the many other native species have a strong and peculiar odour, especially when dried; *H. hircinum* is fœtid.

(REAUMURIACEÆ consist of a few plants scarcely separable from Hypericaceæ. They have shaggy seeds with a small quantity of albumen, and a pair of appendages at the base of the petals. Bentham and Hooker refer them to Tamaricaceæ, from which they differ in their solitary flowers and floury albumen.)

## ORDER XXXII. ELATINACEÆ. WATER PEPPERS.

*Class.* Guttiferæ, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Guttiferales, *Benth. et Hook.*

389. *Diagnosis.*—Little annual marsh-plants, with opposite dotless leaves and membranaceous stipules; flowers minute, axillary;

sepals and petals 2–5; capsule 2–5-celled, with an equal number of styles with capitate stigmas; seeds numerous, exalbuminous.

ILLUSTRATIVE GENERA.

Elatine, *L.* | Bergia, *L.*

**Affinities, &c.**—This little Order consists of a few species scattered all over the world, generally acrid in character. Their relations are variously regarded by different authors: formerly they were placed near *Alsineæ* in Caryophyllaceæ, from which their many-celled ovary divides them; they appear at least equally related to Hypericaceæ, from which they differ in the presence of stipules and the isomerous flowers; they come near to Zygophyllaceæ, as shown by Lindley, the transition being effected through the genus *Anatropa.*

## ORDER XXXIII. SAPINDACEÆ. SOAP-WORTS.

*Class.* Acera, *Endl.* *All.* Sapindales, *Lindl.* *Coh.* Sapindales, *Benth. et Hook.*

390. *Diagnosis.*—Trees, shrubs, or rarely herbs, with simple or compound alternate or opposite leaves; flowers mostly unsymmetrical and irregular, the 4–5 sepals and petals imbricated in æstivation; the latter often provided with a scale at the base; the 5–10 stamens inserted on a fleshy hypogynous or perigynous disk; ovary 2–3-celled and lobed, with 2 (rarely more) ovules in each cell; embryo mostly curved or convoluted, without albumen.

ILLUSTRATIVE GENERA.

Suborder 1. SAPINDEÆ. *Leaves alternate; ovules mostly solitary; embryo curved or sometimes straight.*

Cardiospermum, *L.*
Paullinia, *L.*
Sapindus, *L.*
Cupania, *L.*
Nephelium, *L.*

Suborder 2. HIPPOCASTANEÆ. *Leaves opposite; ovules 2 in a cell, one ascending, the other suspended; embryo curved, with large consolidated cotyledons.*

Æsculus, *L.*
Pavia, *Boerh.*

Suborder 3. DODONEÆ. *Leaves alternate; ovules 2 or 3 in a cell; embryo spiral.*

Kœlreuteria, *Lam.*
Ophiocaryon, *Schomb.*

Suborder 4. MELIOSMEÆ. *Leaves alternate: flowers very irregular, stamens 5, only 2 fertile; ovules 2 in each cell, both suspended; embryo folded up; fruit a drupe.*

Meliosma, *Endl.*

**Affinities.**—Some authors separate the *Hippocastaneæ* and make them a distinct Order, on account of the opposite leaves and the two ovules; and the *Meliosmeæ* on account of the irregular flowers and drupaceous fruits; but these distinctions are esteemed insufficient. These plants are nearly related to Aceraceæ, especially by the samaroid fruits common here: the main distinctions are variable; for the two carpels, the opposite leaves, and the absence of scales on the petals and of an aril may be noted in Sapindaceæ: from Malpighiaceæ, which have samaroid fruit, they are distinguished by their unsymmetrical flowers.

The peculiar convolution of the embryo is a very marked character in many of the Sapindaceæ, and is very curious in *Ophiocaryon*, the Snake-nut. The wood of the stems of some genera, such as *Sapindus*, *Paullinia*, &c., presents anomalous conditions from the distribution of the fibro-vascular structures into several groups, so that the trunks have a number of false woody axes besides that surrounding the pith, all enclosed in a common bark.

**Distribution.**—The members of this large group are natives of the tropics, especially of South America and India; some occur in North America and other temperate regions; the Horse-chestnut is only naturalized in Europe.

**Qualities and Uses.**—The properties of this Order are very various. They take their name from the saponaceous principle contained in the fruits of species of *Sapindus*, *S. Saponaria* &c., which makes a lather with water; hence the fruits are used for washing both in the East and West Indies; the Horse-chestnut, *Æsculus Hippocastanum*, possesses it to a certain extent. The fruits of *Sapindus* are acrid; and the juice of the leaves and bark of some species is poisonous, as are the seeds of *S. senegalensis*. The fruit and leaves of the American Horse-chestnut or Buckeye, *Æsculus ohioensis*, are said to be actively poisonous, while the seeds of *Æ. Hippocastanum* are given to sheep in Switzerland. The Paullinias are very poisonous, from an acrid narcotic principle; yet *P. sorbilis* furnishes in its fruits an article of food for the Brazilian aborigines, called Guarana bread. Other plants produce delicious fruits, such as the Chinese Litchi, the Longan and the Rambutan, from species of *Nephelium*; and the fruits of *Schmidelia edulis* (Brazil), *Melicocca bijuga* (West Indies and Brazil), *Pappea capensis*, *Cupania sapida*, *Paullinia subrotunda*, *Schleichera trijuga*, *Sapindus esculentus*, &c. are all eaten.

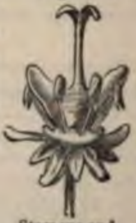
(STAPHYLEACEÆ, comprising a small number of species, were formerly regarded as related to Celastraceæ, but are now placed near Sapindaceæ, from which they differ chiefly in their stipulate, opposite, pinnate leaves, symmetrical flowers, albuminous seeds, and straight embryo. They are of little importance; the species of *Staphylea* are scattered all over the world. *S. pinnata*, the Bladder-nut, a native shrub, has oily and slightly purgative seeds.)

## ORDER XXXIV. ACERACEÆ. MAPLES.

*Class.* Acera, *Endl.* *All.* Sapindales, *Lindl.*

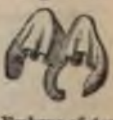
391. *Diagnosis.*—Trees or shrubs with opposite leaves, regular, unsymmetrical, polygamous or diœcious, sometimes apetalous flowers; stamens on a fleshy disk (fig. 353); ovary 2-lobed, 2-celled, with 2 ovules in each cell; fruit a double samara, with 1 seed in each cell; seeds without albumen; cotyledons folded, radicle inferior.

Fig. 353.



Stamens and ovary of *Acer*.

Fig. 354.



Embryo of *Acer* extracted from the seed.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Acer, *L.* | Negundo, *Mœnch.* |

**Affinities.**—Nearly related to Sapindaceæ, and placed with them by Bentham and Hooker, from which, however, they differ in their opposite leaves and petals without scales; allied also to Malpighiaceæ, from which they differ in the absence of glands on the calyx, superior radicle, and other characters.

**Distribution.**—The group consists of 60–70 species, natives of the temperate parts of Europe, Asia, and North America.

**Qualities and Uses.**—Chiefly remarkable for the sap, from which abundance of sugar is obtained in spring, especially from *A. saccharinum* (North America). Their light and handsome timber is also valued for joinery &c. The bark is astringent, and used in dyeing. *A. campestre*, native Maple, and *A. pseudo-Platanus*, the Sycamore, are common trees in Britain. *Negundo* and various other kinds of Maple have been introduced from North America on account of their beauty as ornamental trees, especially in autumn.

## ORDER XXXV. POLYGALACEÆ. MILK-WORTS.

*Class.* Polygalinæ, *Endl.* *All.* Sapindales, *Lindl.* *Coh.* Polygalineæ, *Benth. et Hook.*

392. *Diagnosis.*—Herbs or shrubs with alternate, exstipulate, simple leaves; irregular hermaphrodite flowers; 4–8 diadelphous or monadelphous stamens; the anthers 1-celled, opening at the apex by a pore or chink; fruit a 2-celled, 2-seeded pod; seeds carunculated.

### *Character.*

*Calyx*: *sepals* 5, very irregular, distinct, often membranaceous; 3 placed exterior, 1 behind and 2 in front, the interior 2 (*wings*) lateral, usually petaloid.

*Corolla*: *petals* usually 3, 1 anterior and large (*keel*) and 2 posterior, between the wings and posterior sepal of the calyx, and often coherent with the keel; sometimes 5, the additional 2 small, and placed between the wings and the anterior sepals on each side; the *keel* entire and with a fringe or crest, or 3-lobed and without a crest.

*Stamens* hypogynous, 8, coherent in a tube, unequal and ascending; the tube split opposite the back sepal; or 4, distinct; *anthers* clavate, 1-celled, and opening by a terminal pore, or 2-celled.

*Ovary* compound, 2–3-celled, one cell always suppressed in some cases; *ovules* suspended, solitary or twin; *style* and *stigma* simple, sometimes hooded.

*Fruit* various, dry or succulent, sometimes winged; *seeds* pendulous, naked or with a hairy coat, a caruncle next the hilum; *embryo* straight or nearly so, in abundant albumen.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Salomonia, *Lour.* | Monnina, *Ruiz & Pav.* |
| Polygala, *L.* | Securidaca, *L.* |
| Mundia, *Kunth.* | Xanthophyllum, *Roxb.* |

Krameria, *Lœffl.* (?)

**Affinities.**—The relations of the Polygalaceæ have been a subject of much discussion among botanists. The irregular corolla, somewhat papilionaceous in *Polygala*, has led to a comparison to Leguminosæ, from which, however, they differ widely; moreover the odd petal is anterior in Polygalads, not next the axis as in Leguminosæ. The irregular petals, together with the hooded stigma, have suggested a relationship to Violaceæ; *Krameria* has been referred by some writers to the Cæsalpineous division of the Leguminosæ. Most authors, however, are agreed that the nearest affinity is to Sapindaceæ. *Krameria* is raised to the rank of a distinct Order by a few writers, on account of the different corolla, composed of 5 petals, 4 (often free) stamens, and 1-celled ovary.

**Distribution.**—A large Order, nearly half the species of which are comprised in the genus *Polygala* and are very generally distributed; the others are mostly confined to particular quarters of the globe.

**Qualities and Uses.**—The plants of this Order are mostly bitter, and acrid or astringent, with a milky juice in the root. The common Milkwort, *P. vulgaris*, and especially the form called *P. amara*, possesses bitter properties, but in less degree than *P. rubella* of North America. *Soulamia amara* (Molucca) is said to be intensely bitter. The more active species of *Polygala* have emetic, purgative, and diuretic properties: *P. Senega*, the American Snake-root, with *P. sanguinea* and *purpurea*, the Cape *P. Serpentaria*, the European *P. chamæbuxus*, and the *P. crotalarioides* of the Himalayas &c., all show this property; and they are likewise all reputed antidotes against the poison of snakes. *P. venenosa* (Java) is regarded as a poison, the properties being excessively concentrated. *P. tinctoria* (North America) is used in dyeing. The bark of the root of a species of *Mundia* contains a saponaceous substance, and is used for washing. *Krameria triandra* and other species, called Rhatany, are remarkable for the powerful astringent quality of the roots, which gives a deep red colour to an infusion. Rhatany-root is used in medicine, and is employed also to adulterate Port wine.

(TREMANDRACEÆ are a small Order of plants related to Polygalaceæ, but with a regular, symmetrical flower, valvate calyx, free stamens, and seeds hooked at the chalazal end. They may be regarded as regular-flowered Polygalas. De Candolle placed them between Polygalaceæ and Pittosporaceæ. They are slight, heathy shrubs, growing in Australia; 16 species are known, belonging to the genera *Tremandra*, *Tetratheca*, and *Platytheca*. They derive their names from the porous dehiscence of the anthers, and are of no known use.)

## ORDER XXXVI. MALPIGHIACEÆ.

*Class.* Acera, *Endl.* *All.* Sapindales, *Lindl.*

393. *Diagnosis.*—Trees or shrubs, often climbers, with usually opposite or whorled, rarely alternate leaves; stipules generally short and deciduous, occasionally large and opposite the leaves; flowers perfect, or polygamous; calyx and corolla 5-merous, calyx with glands at the base of 1 or of all the segments; petals clawed; stamens mostly 10, often monadelphous with a thickened produced connective; carpels 3, or very rarely 2 or 4, wholly or partly coherent, often keeled; ovules solitary in the cells, pendulous from long funiculi; seeds exalbuminous; embryo with mostly convolute thick or leafy cotyledons.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Malpighia, *Plum.* | Nitraria, *L.* |
| Byrsonima, *Rich.* | Banisteria, *L.* |

**Affinities, &c.**—The closest relations of this Order are Sapindaceæ and Aceraceæ, from which they are distinguished by their symmetrical flowers, and generally by the glands in the calyx, the long stalks to the petals, the small disk, and solitary ovule. Some of the climbing kinds have stems of anomalous structure with several woody axes, without annual rings, enclosed in a common bark, or ultimately more or less separated from one another. *Nitraria*, a genus of saline plants, is sometimes separated as a distinct Order. The Order is a large one, comprising many genera and species, which latter are mostly Tropical-American. Their properties are generally unimportant; many of them have been introduced into our stoves on account of their showy flowers. The fruits of *Malpighia glabra* and *punicifolia* are eaten in the West Indies, under the name of Barbadoes Cherries. Munby supposes the sedative or semi-intoxicating drupe of *Nitraria tridentata* (North Africa) to have been the Lotus of the ancients. The bark of most kinds is astringent; the hairs of some Malpighias sting powerfully.

(ERYTHROXYLACEÆ are by some authors separated from the Malpighiaceæ on account of the calyx having no glands, while the petals present two membranous plates, on account of their capitate stigmas, and the absence of a long funiculus to the anatropous ovule. They are closely allied to *Linaceæ*, with which, indeed, they are associated by Bentham and Hooker, but differ in the presence of scales to the petals, their drupaceous fruit, and woody stem. They are shrubs, mostly belonging to one genus, *Erythroxylon*, and found most abundantly in Brazil; but a few are scattered all over the globe. They receive their name from the red colour of the wood of some kinds, such as *Erythroxylon hypericifolium* (Mauritius). The most remarkable plant of the Order is *E. Coca*, the leaves of which, under the name of Coca or Ipadu, are largely consumed in Peru and in Equatorial America, to produce a kind of intoxication; "Coca" is said to enable the natives to go two or three days without food; it is mixed with powdered chalk and chewed. Several species of *Erythroxylon* are recorded, and two or three belonging to other Genera.)

## ORDER XXXVII. CEDRELACEÆ. THE EBONY ORDER.

*Class.* Hesperides, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Geraniales, *Benth. et Hook.*

394. *Diagnosis.*—Timber trees with alternate, pinnate, exstipulate leaves; calyx and corolla 4–5-merous; stamens 8–10, distinct, inserted in an hypogynous disk; ovary with 4–5 cells or 3; ovules 4 or more, in 2 rows; fruit capsular, the valves separating from an angular column; seeds flat, winged; albumen thin or none.

ILLUSTRATIVE GENERA.

Swietenia, *L.* | Flindersia, *R. Br.* | Cedrela, *L.*

**Affinities, &c.**—Nearly related to Meliaceæ, and included in that family by most recent authors. The species are distinguished chiefly by the free stamens and the numerous winged seeds. *Chloroxylon* and *Flindersia* have dotted leaves. The plants are most common in the tropics of America and India. They have fragrant, aromatic, and tonic properties, and their timber is valuable. *Swietenia Mahogani* is the Mahogany-tree; its bark, and that of *Cedrela Toona, febrifuga*, and other species, are used as substitutes for Cinchona. *Chloroxylon Swietenia* furnishes East-Indian Satinwood; and an oil called Wood-oil is obtained from it. *Oxleya xanthoxyla* is the Yellow-wood of Australia.

## ORDER XXXVIII. MELIACEÆ.

*Class.* Hesperides, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Geraniales, *Benth. et Hook.*

395. *Diagnosis.*—Trees or shrubs with alternate or somewhat opposite, simple or pinnate leaves, without stipules; flowers sometimes diclinous by abortion; calyx and corolla 3-, 4-, or 5-merous; stamens twice as many, coherent in a long tube; anthers sessile in the orifice of the tube; hypogynous disk sometimes cup-like; ovary compound, few- or many-celled; style 1; ovules 1–2, rarely 4 in a cell; fruit succulent or capsular, often 1-celled by abortion; seeds not winged; albumen fleshy or absent.

ILLUSTRATIVE GENERA.

Melia, *L.*
Lansium, *Rumph.*
Guarea, *L.*
Carapa, *Aubl.*

**Affinities, &c.**—Nearly related to Cedrelaceæ and Aurantiaceæ. A more distant affinity is with Sapindaceæ and Rutaceæ. The species are numerous, and are found in the hotter parts of the globe generally; they possess bitter and astringent properties; some are powerfully purgative and emetic, such as *Guarea Aubletii* and *trichilioides*, *Trichilia emetica*, &c. *Melia Azedarach*, the Neem-tree, or Margosa, of the East Indies, is supposed to have febrifugal properties; its succulent pericarp yields an oil; and a kind of toddy is obtained by tapping it. *Carapa guineensis* yields a purgative oil, which is used also for lamps. *Lansium*, a genus of the East-Indian archipelago, yields an edible fruit called Langsat or Lanseh and Ayer-Ayer.

## ORDER XXXIX. AURANTIACEÆ. THE ORANGE ORDER.

*Class.* Hesperides, *Endl.* *All.* Rutales, *Lindl.*

396. *Diagnosis.*—Trees or shrubs with smooth, glandular alternate leaves, the blade jointed to the petiole; flowers regular, hermaphrodite, 3–5-merous; petals and stamens inserted on an hypogynous disk; stamens with flat filaments, distinct or coherent into one or several parcels; ovary many-celled, style single, terminal; fruit pulpy, often with a glandular leathery rind; seeds without albumen; embryo with thick fleshy cotyledons and a short radicle next the hilum.

### ILLUSTRATIVE GENERA.

Triphasia, *Lour.*
Rissoa, *Arn.*
Bergera, *Kœn.*
Cookia, *Sonner.*
Feronia, *Corr.*
Ægle, *Corr.*
Citrus, *L.*

**Affinities.**—The plants of this Order are by Bentham and Hooker classed as a tribe of *Rutaceæ*, and are nearly related to the Meliaceæ in the structure of the flowers, and still more closely to Amyridaceæ. In general they are distinguishable by the dotted leaves, with the blade (simple or compound) articulated to the petiole, the deciduous imbricated petals, and the succulent fruit. The relation to Rutaceæ is rendered clearer by occasional monstrosities of the fruit, from which some of the carpels grow out like horns. Sometimes a second circle of carpels is produced, forming, as it were, a double concentric fruit, comparable in some measure to the conditions in the Pomegranate, where, however, the whole fruit is enclosed in the excavated receptacle. The seeds of Oranges often contain two embryos; and they are remarkable for the development of ramified collections of spiral vessels at the chalazal end, within the testa, also for a peculiar coloration of the inner coat of the seed in this situation.

**Distribution.**—Chiefly East-Indian plants, but diffused by cultivation throughout the tropics, and even in the warmer temperate regions.

**Qualities and Uses.**—The most remarkable parts of these plants are their fruits; those of the genus *Citrus* being among the most valuable and best-known of imported fruits. The species of *Citrus* are not clearly defined, much difference of opinion existing as to the specific distinctness of certain forms, which, as in most cultivated plants, are much confused. *C. Aurantium* is the common Sweet Orange; *C. Bigaradia* or *C. vulgaris*, the bitter or Seville Orange, seems to be known only in cultivation, and is supposed by some to be a variety of the preceding. *C. Bergamia* is the Mellarosa or Bergamot Orange, which is also regarded as a variety of *C. Limetta*, the cultivated Sweet Lime; *C. acida* is the East-Indian Lime; *C. Limonium* is the ordinary Lemon; *C. Lumia* is the Sweet Lemon, cultivated in the South of Europe; *C. medica* is the Citron; *C. decumana* is the Shaddock; *C. Paradisi* the Forbidden-fruit; *C. Pompelmos* the Pompelmoose; and *C. japonica* the Kumquat. All these fruits have an abundant pulp, which varies chiefly in the degree of acidity and the peculiar aroma; that of *C. Bigaradia* is also bitter. The rind of all is fragrant, from the presence of imbedded glands containing essential oil of aromatic and bitter character; the flowers partake of the aromatic quality. The oil of Neroli is obtained from the flower of *C. Bigaradia*; but the oil of the rind is also used for making Orange-flower water. Oil of Bergamot is from the flower and rind of the fruit of *C. Bergamia*; *huile de Cédrat* from *C. medica*; the essential oil of the Lemon-rind is also largely used. The rinds are also valued for their bitter and aromatic properties when dried or preserved with sugar. The dry rinds of Orange, Lemon, &c. are used as stomachics in medicine, in infusions and tinctures; and are also employed in the preparation of liqueurs and cordials, such as Curaçoa &c.; the fruit, rind, and pulp, when preserved with sugar, form "marmalade," the best being made from the Seville Orange. The acidity of the Lime and Lemon depends chiefly on the presence of citric acid, and renders them very valuable as antiscorbutic agents. *Ægle Marmelos* has a delicious fruit, which, however, is laxative. The rind is used as a vermifuge. *Cookia punctata* yields the Wampee, highly valued in China and the East-Indian archipelago; and the fruits of other plants of the Order are eaten. The wood of all the trees is hard and compact; the foliage shares the fragrant character of the fruits, containing abundance of glands filled with aromatic, bitter essential oils. The Orange, Lemon, and their varieties are largely cultivated in the South of Europe in the open air; and in our conservatories they are everywhere prized, both on account of their striking appearance when in fruit and the delicious perfume of the flowers. Orange- and Lemon- trees are wonderfully prolific of fruit; and the plants retain their vitality with great obstinacy when taken from the ground and transported to a distance, and when they are multiplied by cuttings.

## ORDER XL. LINACEÆ. THE FLAX ORDER.

*Class.* Gruinales, *Endl.* *All.* Geraniales, *Lindl.* *Coh.* Geraniales, *Benth. et Hook.*

397. *Diagnosis.*—Herbs, or sometimes shrubs, without stipules; with regular symmetrical hermaphrodite flowers, 4–5-merous throughout; calyx imbricated; petals convolute in æstivation; stamens 5, coherent at the base, often with intervening sterile stamens; ovary compound, of about as many carpels as there are sepals; styles distinct; capsule many-celled, each cell divided more or less perfectly into two by a false septum from the dorsal suture, each compartment with one seed, having a straight oily embryo and with, or rarely without, albumen.

### ILLUSTRATIVE GENERA.

Linum, *L.* | Radiola, *Dillen.*

**Affinities.**—Most nearly related to Oxalidaceæ, but likewise connected with Caryophyllaceæ, Malvaceæ, and Geraniaceæ by the general structure of the flowers, the coherent stamens, &c.; but the simple entire leaves and the peculiar structure of the capsule are very distinctive marks. From Malpighiaceæ they differ in their glandless calyx.

**Distribution.**—A small Order, generally diffused, but most abundantly so in Europe and North Africa.

**Qualities and Uses.**—*Linum catharticum*, a native weed, has active purgative properties; but the most important plant of the Order is *L. usitatissimum*, the liber-fibres of which constitute Flax, while the seeds, known as Linseed, yield a most valuable drying-oil, and their cake forms an excellent material for fattening cattle. The flowers of many species of *Linum* are very showy (blue, yellow, pink, &c.), but are mostly fugacious.

## ORDER XLI. OXALIDACEÆ. WOOD-SORRELS.

*Class.* Gruinales, *Endl.* *All.* Geraniales, *Lindl.*

398. *Diagnosis.*—Herbs, or rarely shrubs or trees, with an acid juice; mostly compound leaves; regular, symmetrical, hermaphrodite, 5-merous flowers; calyx imbricated, and petals convolute in æstivation; stamens 10, somewhat monadelphous; styles 5, separate; capsule 5-celled, several-seeded; seeds albuminous; embryo straight or curved.

### ILLUSTRATIVE GENERA.

Oxalis, *L.* | Averrhoa, *L.*

**Affinities.**—Nearly related to Geraniaceæ, with which Bentham and Hooker unite them. From Linaceæ they may generally be distinguished by their compound leaves and albuminous seeds; but the septa or the capsules of that Order afford the most constant distinction. The seeds of *Oxalis* have an elastic fleshy coat, which opens with elasticity and expels the seed when ripe. Some regard this as an aril, others as a development of the testa. The leaves of many kinds are sensitive, especially *Oxalis sensitiva* and *Averrhoa Bilimbi*; but others possess the quality in lower degree. *O. bupleurifolia* and some other species have phyllodes (§ 71).

**Distribution.**—A rather large Order, the members of which are generally diffused in temperate and hot climates; most abundant in America and at the Cape of Good Hope. The shrubby kinds belong to hot climates.

**Qualities and Uses.**—The most marked property of *Oxalis* is the acid juice, depending on the presence of oxalic acid. *O. Acetosella*, Wood-sorrel, abounds in our woods. *Averrhoa Bilimbi*, the Blimbing, *A. Carambola*, the Carambole of the East Indies, have acid fruits, which are eaten by the natives, but used chiefly as pickles by Europeans. Some species of *Oxalis* have tubers furnishing wholesome food. *O. crenata* (Arracacha) is used like potatoes in Columbia; *O. Deppei* has roots as large as small parsnips. The tubers of *O. anthelmintica*, the Mitcha-mitcho of Abyssinia, are said to be valuable as an anthelmintic. Many kinds are cultivated on account of the beauty of their flowers.

## ORDER XLII. GERANIACEÆ. CRANE'S-BILLS.

*Class.* Gruinales, *Endl.* *All.* Geraniales, *Lindl.* *Coh.* Geraniales, *Benth. et Hook.*

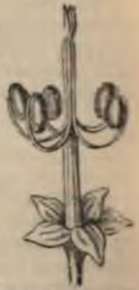
399. *Diagnosis.*—Herbs or shrubs, with articulated swollen stem-joints; opposite or alternate leaves, and membranous stipules; regular or irregular, symmetrical, hermaphrodite, 5-merous flowers; sepals imbricated and petals convolute in æstivation; stamens mostly 10, coherent at the base, the alternate ones shorter and sometimes barren;

carpels 5, adherent to a central prolonged axis (carpophore), from which they separate when ripe by the elastic curling-back of the segments of the style, carrying away the 1-seeded dehiscent cocci.

### *Character.*

*Calyx*: *sepals* 5, ribbed, persistent, more or less unequal, imbricated in the bud.

Fig. 355.



Fruit of *Geranium*, with the carpels dehiscent.

*Corolla*: *petals* 5, or rarely 4 (by abortion), clawed, equal or unequal, twisted in æstivation, sometimes perigynous.

*Stamens* mostly monadelphous, hypogynous, 10 or 15, some occasionally abortive.

*Ovary* of 5 carpels cohering with their long styles to an elongated column from the apex of the receptacle, each 1-celled, 2-ovuled; *stigmas* distinct.

*Fruit* composed of 5 1-seeded carpels, which separate below from the central carpophore (fig. 355), their persistent styles curling up and remaining attached at the summit; each carpel bursting internally to discharge its seed; *seed* exalbuminous, with a convoluted embryo.

### ILLUSTRATIVE GENERA.

Erodium, *Hérit.*
Geranium, *Hérit.*
Monsonia, *L.*
Pelargonium, *Hérit.*

**Affinities.**—Many points of affinity exist with Oxalidaceæ, Linaceæ, and Balsaminaceæ, likewise with Tropæolaceæ, and, less important ones with Zygophyllaceæ. The arrangement of the carpels round a column, the palmate leaves of some kinds, the monadelphous stamens, and the convoluted embryo cause a good deal of resemblance to some of the Malvaceæ. The peculiar fruit, the stipules, the swollen joints of the stem, and the convoluted embryo separate this Order from the nearest allies; from Malvaceæ it may be distinguished at once by the imbricated æstivation of the calyx. *Pelargonium* is remarkable for a spur or pouch extending from the base of the calyx and adherent to the peduncle. Most of the plants have aromatic oil contained in glandular hairs, giving a musky or other strong odour.

**Distribution.**—The species are numerous. *Geranium* and *Erodium* belong chiefly to the temperate parts of the Northern Hemisphere. *Pelargonium* abounds at the Cape of Good Hope, and occurs in Australia. One species is found in Asia Minor.

**Qualities and Uses.**—Astringent and aromatic properties are general. The common weed *G. Robertianum*, had a reputation formerly, and the *G. maculatum*, or Alum-root of North America, is a powerful astringent, containing a large amount of tannin. The species of *Erodium* which emit a musky odour are said to have similar properties. Some have tuberous roots; that of *Pelargonium triste* is eaten at the Cape of Good

Hope. The species of *Pelargonium* are remarkable for the beauty of their flowers, which are more or less irregular and spurred, and have great susceptibility of improvement by culture, and a tendency to run into varieties, rendering them established "florist's flowers." Many of them have zones or belts of colour in the leaves. The species of *Geranium* proper have regular flowers without spurs.

## ORDER XLIII. BALSAMINACEÆ. BALSAMS.

*Class.* Gruinales, *Endl.* *All.* Geraniales, *Lindl.*

400. *Diagnosis.*—Annual plants with succulent stems, full of bland watery sap; flowers hermaphrodite, very irregular; stamens 5, somewhat united; the fruit mostly bursting elastically when ripe. Embryo straight, exalbuminous.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Impatiens, *L.* | Hydrocera, *Blum.* |

*Affinities, &c.*—This Order is nearly related to Geraniaceæ, and is included in that family by Bentham and Hooker, but may be distinguished by the want of the peculiar carpophore of that Family, and by the much greater irregularity of the flower; the irregular flower also separates it from Oxalidaceæ and other allied Orders. This irregular flower does not really depart widely from a symmetrical condition: it is completely 5-merous, except in the suppression in *Impatiens* of the petal opposite the bract (which is developed in *Hydrocera*); the two small lateral sepals, the spur, and the double segment on the opposite side to the spur form an imbricated calyx of five parts; the odd petal opposite the two confluent sepals is suppressed, and the others are generally combined into two 2-lobed bodies, but are sometimes free; in single flowers the stamens alternate with these; in double cultivated flowers a second corolline circle of five petals sometimes appears in the place of the stamens, and the stamens alternate again with these. The structure of the ovary and its mode of dehiscence are also deserving of notice. The name of the genus *Impatiens* is derived from the elasticity with which the capsule bursts when touched after the seeds are ripe. The species are rather numerous. A few are scattered over the globe; but the majority are East-Indian. Their properties are unimportant. *I. Balsamina* is a valued tender annual plant; *I. Noli-me-tangere* grows in the north of England; and *I. fulva* (North America) is naturalized in some places in Southern England.

(VIVIANACEÆ are a small Order of South-American herbs or half-shrubby plants, related to Geraniaceæ, but having a valvate calyx and albuminous seeds. Properties unknown.)

## ORDER XLIV. TROPÆOLACEÆ. GARDEN-NASTURTIUMS.

*Class.* Gruinales, *Endl.* *All.* Malvales, *Lindl.*

401. *Diagnosis.*—Smooth trailing or climbing herbs with a pungent juice; leaves alternate, exstipulate; flowers axillary, irregular, perfect; sepals

3–5, the upper one spurred; petals 1–5; stamens 6–10, perigynous, distinct; ovary superior, of 3 or 5 carpels; style single; stigmas 3–5; ovules pendulous, 1 in each carpel; fruit dry; carpels separating as indehiscent achenes from a central axis; seeds large, exalbuminous.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Tropæolum, *L.* | Chymocarpus, *Don.* |

**Affinities, &c.**—A small Order of plants, natives of the temperate parts of South America, related to Malvaceæ and Geraniaceæ, and included in the latter Family by Bentham and Hooker. The genus *Tropæolum* contains the garden Nasturtiums, or Indian Cresses, notable for their pungent juice, somewhat like that of Cruciferæ. Various species have a tuberous root; that of *T. tuberosum* is eaten in Peru. The spur of the calyx of *Tropæolum* is curious, resembling that of *Pelargonium*, but is free from the peduncle. In some cases it would seem to be a tubular process from the receptacle. The flowers are mostly showy and of great variety of colour. The Canary Creeper, *T. peregrinum* or *aduncum*, may be noticed for the power of the full-grown plant to obtain its nourishment apparently almost entirely from the atmosphere, and for its climbing by twining its petioles, like *Clematis.*

(LIMNANTHACEÆ, a small Order of North-American plants, are chiefly distinguished from Tropæolaceæ, with which they are associated in the family *Geraniaceæ* by Bentham and Hooker, by their regular flowers, erect ovules, and the adherence of the stamens to the calyx. Their properties are analogous. *Limnanthes* (California) has showy flowers. *Flœrkia* (United States) is a mere weed.)

## ORDER XLV. ZYGOPHYLLACEÆ. BEAN-CAPERS.

*Class.* Terebinthinæ, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Geraniales, *Hook. et Benth.*

402. *Diagnosis.*—Herbs, shrubs, or trees with opposite stipulate, mostly imparipinnate, not dotted leaves; calyx and corolla 4–5-merous, imbricated in æstivation; stamens twice as many, hypogynous, each usually at the back of a scale; ovary simple, surrounded by glands or a toothed disk, more or less deeply 4–5-lobed, 4–5-celled; fruit capsular; dehiscence valvular or into cocci; few-seeded; albumen sparing or none.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Tribulus, *Tournef.* | Zygophyllum, *L.* | Melianthus, *L.* (?) |
| Peganum, *L.* | Larrea, *Cav.* | |
| Fagonia, *Tournef.* | Guaiacum, *Plum.* | |

**Affinities.**—This Order is very closely allied to Rutaceæ (but differs in habit, the scaly stamens, and dotless leaves) through *Peganum*, which is placed here chiefly on account of its stipulate, not dotted, opposite leaves.

With Simarubaceæ it agrees in the attachment of the stamens at the back of a scale, but differs in the short styles. *Melianthus* is an anomalous genus, which by some authors is taken as the type of a distinct Order supposed to have its nearest relations in Geraniaceæ and Sapindaceæ. They are closely related to Malpighiaceæ, but differ in their glandless calyces, scaly stamens, &c.

**Distribution.**—The species are not very numerous, and are chiefly found in the warm temperate regions of the globe. *Zygophyllum* and *Tribulus* are especially characteristic of dry regions of Egypt, Arabia, and Scinde.

**Qualities and Uses.**—The so-called gum-resin, Guaiacum, is derived from *Guaiacum officinale*, the bark and wood of which are also employed as diaphoretic and sudorific agents; *G. sanctum* has similar properties. The leaves of these and of *Porliera* are used in place of soap for scouring in the West Indies. The remarkably hard wood called Lignum Vitæ is derived from *Guaiacum officinale* or some other species; all the arborescent plants of this Order have extremely hard wood. The flowers of *Zygophyllum Fabago* are used in the East for pickles, under the name of Bean-capers. The seeds of *Peganum Harmala* are used as spice in Turkey, and also in the production of the celebrated Turkey-red dye for cotton. *Larrea mexicana* is known by the name of the Creasote-plant. *Zygophyllum simplex* has a very bad odour.

## ORDER XLVI. RUTACEÆ. THE RUE ORDER.

*Class.* Terebinthinæ, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Geraniales, *Benth. et Hook.*

408. *Diagnosis.*—Herbs or trees with simple or compound exstipulate leaves, dotted with transparent glands containing aromatic or acrid oil; flowers regular, 3–5-merous; the stamens equal to or twice as many as the sepals; the 2-5 pistils separate or combined into a compound ovary with as many cells, sessile or raised on a prolongation of the receptacle (gynophore) or glandular disk; style simple, or divided below; fruit with the carpels either coherent or separating and bursting by one or both sutures; seeds in pairs or solitary; albumen present or absent, radicle superior.

### ILLUSTRATIVE GENERA.

Galipea, *Aubl.*
Ticorea, *Aubl.*
Esenbeckia, *H., B., K.*
Boronia, *Smith.*

Eriostemon, *Smith.*
Correa, *Smith.*
Diosma, *L.*

Barosma, *Willd.*
Dictamnus, *L.*
Ruta, *Tournef.*

**Affinities, &c.**—This large Order is sometimes divided into two, Rutaceæ and Diosmeæ, the latter including the greater part of the genera; but the distinctions seem insufficient—the *Boronieæ*, which have the separable endocarp supposed to be characteristic of *Diosmeæ*, having albuminous seeds like *Ruteæ*. The Order is connected with Zygophyllaceæ by *Peganum*; it is related also to Xanthoxylaceæ, which are perhaps merely polygamous Rutaceæ. There is also an affinity with Aurantiaceæ (which differ, however, in the fruit), and with Anacardiaceæ. *Correa*, with its monopetalous corolla, seems to approach Ericaceæ, to which the *Boronieæ* have much resemblance in habit. From Simarubaceæ and Terebinthaceæ Rutals differ in their glandular leaves and in the nature of the fruit.

**Distribution.**—*Ruta* and its allies are found chiefly in Europe and North Asia: *Diosma, Barosma,* &c. at the Cape of Good Hope; *Boronia, Eriostemon,* &c. in Australia; and *Galipea, Esenbeckia,* and their related genera in Equinoctial America.

**Qualities and Uses.**—Generally remarkable for a strong aromatic or fœtid odour, and possessing antispasmodic and tonic properties. Angostura bark is derived from *Galipea officinalis,* and apparently from *G. Cusparia (Bonplandia trifoliata)*; Melambo bark probably from some allied plant. The bark of *Esenbeckia febrifuga* is used in place of Cinchona in Brazil; and that of *Ticorea febrifuga* is another of the "Quinas" of Brazil. The Bucku plants of South Africa are species of *Barosma, Diosma,* and their allies; their foliage, which is extremely glandular, has a very strong odour; and *D. crenata, serratifolia,* and others are used as antispasmodic and diuretic agents. The leaves and unripe fruits of Rue (*Ruta graveolens*) are antispasmodic, and are also said to be emmenagogue and anthelmintic: *R. montana* is acrid; and its juice is described as vesicating the skin, and even producing erysipelas and ulceration. The leaves of *Correa alba* and other species are used by the settlers in Australia for Tea. Many of the Rutaceæ are favourite greenhouse plants, such as *Boronia, Eriostemon,* &c. *Dictamnus Fraxinella,* a South-European plant, common in our gardens, is very glandular, and it is said that the volatile oil renders the atmosphere about the plant inflammable in very hot weather. This account requires confirmation. These glandular plants are of course very inflammable in themselves.

## ORDER XLVII. XANTHOXYLACEÆ. THE PRICKLY-ASH ORDER.

*Class.* Terebinthinæ, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Geraniales, *Benth. et Hook.*

404. *Diagnosis.*—Trees or shrubs with alternate or opposite, simple or compound, dotted leaves, and flowers resembling those of Rutaceæ in almost every respect except that they are constantly polygamous, and sometimes have succulent fruit; seeds albuminous.

### ILLUSTRATIVE GENERA.

Xanthoxylon, *Kunth.* | Ptelea, *L.*

**Affinities.**—The Xanthoxylaceæ are united by some authors with the Rutaceæ; their more remote relations are with Aurantiaceæ and Anacardiaceæ, which, however, not only differ in their fruits, but their seeds have no albumen. There is a considerable affinity to the Euphorbiaceæ and to *Fraxinus* among the Oleaceæ, *Ptelea* having even a samaroid fruit.

**Distribution.**—The species are not very numerous, and are generally distributed, but are most abundant in America.

**Qualities and Uses.**—Pungent and aromatic. *Xanthoxylon,* a genus represented in North and South America, as well as in India, China, &c., eminently possesses these characters, its species being commonly called Peppers in their native countries. *X. Clava* and *fraxineum* (North America) are powerful diaphoretics and sudorifics; *X. nitidum* (China) has a similar reputation; *X. hyemale* (Brazil), *X. piperitum* (China), &c. are analogous. The unripe capsules of *X. Rhetsa* are aromatic, resembling orange-peel. The fruit of *Ptelea* has a strong aromatic bitter taste, and has been used as a substitute for hops.

## ORDER XLVIII. SIMARUBACEÆ. THE QUASSIA ORDER.

*Class.* Terebinthinæ, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Geraniales, *Benth. et Hook.*

405. *Diagnosis.*—Trees or shrubs with alternate exstipulate leaves, without dots, usually compound; calyx and corolla 4–5-merous; stamens 8–10, each on the back of a scale; anthers bursting longitudinally; ovary stipitate, 4–5-lobed; fruit of 4–5 indehiscent drupes round a common receptacle, or capsular or samaroid, with 1 pendulous exalbuminous seed in each compartment.

ILLUSTRATIVE GENERA.

Quassia, *L.*
Simaba, *Aubl.*
Simaruba, *Aubl.*
Ailanthus, *Desf.*
Picrasma, *Blume.*
Brucea, *Miller.*

**Affinities.**—Belonging to the Rutaceous group, these plants are most closely allied to the Zygophyllaceæ by the stamens and dotless leaves, to the Ochnaceæ by the deeply lobed ovary,—differing from the former in the structure of the fruit and the number of seeds in a cell, from the latter by the absence of a large disk and the dehiscence of the stamens.

**Distribution.**—A small Order, the members of which inhabit South America, Africa, the East Indies, and the Malay archipelago. *Cneorum* occurs in the Mediterranean district.

**Qualities and Uses.**—The most striking property is great bitterness, whence they are used as tonics. Quassia or Bitter-wood, used as a tonic, as a fly-poison, and as a substitute for hops in beer, is derived from this family. *Quassia amara* (Surinam) is stated to be the true plant; but *Picrasma*, or *Picræna excelsa* yields the wood usually imported. The bark of the root of *Simaruba amara* is used in the same manner. *Brucea antidysenterica* has similar qualities, and was formerly mistakenly supposed to be the source of false Angostura bark. *Simaba Cedron* has a reputation for curing snake-bites; but recent experiments throw doubt on this. *Ailanthus glandulosa*, the "tree of heaven," is commonly grown for ornament in this country; its leaves afford nutriment to a species of silkworm.

(OCHNACEÆ are scarcely separable from Simarubaceæ; but the ovary is composed of carpels seated on a large fleshy disk instead of upon a stipe, the elongated anthers often open by pores, and the simple leaves are without stipules. The thick gynophore of this Order affords a close connexion between Rutaceæ and Geraniaceæ. The properties are similar to those of Simarubaceæ.)

(CORIARIEÆ is the name applied to a small group of plants belonging to one genus, *Coriaria*, of obscure affinities, placed in this neighbourhood by Lindley, but differing from most of the Rutales in their pendulous ovules with dorsal raphe. In some respects they approach *Phytolaccæ*. These plants have dangerous properties. Of *C. myrtifolia* the leaves, which are sometimes used to adulterate Senna, are said to produce tetanus; the berries are poisonous. The fruits of other species are said to be edible, but the seeds poisonous. *C. myrtifolia* and *ruscifolia* are used in dyeing, infusion of the leaves giving a dark blue with sulphate of iron.)

## ORDER XLIX. PITTOSPORACEÆ.

*Class.* Frangulaceæ, *Endl.* *All.* Berberales, *Lindl.* *Coh.* Polygalinæ, *Benth. et Hook.*

406. *Diagnosis.*—Trees or shrubs, often climbing plants, with alternate exstipulate leaves; flowers regular; calyx and corolla 4–5-merous, imbricated, deciduous; stamens 5, hypogynous, alternate with the petals, opening longitudinally or by apical pores; ovary free; cells or placentas 2 or more; style single; stigmas equal to the placentas; ovules horizontal or ascending; seeds numerous; embryo minute, in fleshy albumen.

### ILLUSTRATIVE GENERA.

Pittosporum, *Soland.*
Cheiranthera, *Cunningh.*
Sollya, *Lindl.*
Billardiera, *Smith.*

**Affinities, &c.**—A small Order, placed by DeCandolle between Polygalaceæ and Frankeniaceæ, by A. Richard near Rutaceæ, by Endlicher in the neighbourhood of Rhamnaceæ. Lindley regards them as near Vitaceæ. From Tremandraceæ and Olacaceæ they differ in their imbricate sepals and petals and their numerous ovules. In other points they resemble Celastrineæ, but they have no disk and no aril. Decaisne points out an affinity with some Ericads, as *Ledum*. The plants are chiefly from Australia; the berries of *Billardiera* are eaten, having a pleasant acid flavour; but a resinous quality pervades the whole Order. Some of the species are cultivated on account of their flowers and coloured berries, as *Sollya*, *Billardiera*, &c.

## ORDER L. VITACEÆ. VINES.

*Class.* Discanthæ, *Endl.* *All.* Berberales, *Lindl.* *Coh.* Celastrales, *Benth. et Hook.*

407. *Diagnosis.*—Shrubs with a watery juice, usually climbing by tendrils, with small regular flowers, a minute truncated calyx with the limb mostly obsolete; stamens as many as the valvate petals, and opposite to them, springing from a disk surrounding the ovary. Fruit succulent; seeds bony; albumen hard.

### Illustrative Genera.

Cissus, *L.*
Vitis, *L.*
Pterisanthes, *Blum.*
Leea, *L.*

**Affinities.**—The relations of this Order are somewhat complex: a portion of the plants are related to Meliaceæ, Celastrineæ, and Rhamnaceæ; but the nearest connexion would appear to be to the epigynous Order Araliaceæ, especially through the Ivy, *Hedera.* The characters of the group, however, are very distinct, in the hypogynous stamens opposite the petals, and the climbing habit. The tendrils by which the stems climb are flower-branches, often exhibiting a few nodules representing abortive flowers; in some cultivated Vines the seeds are constantly suppressed, while the fruit is perfected, as in the varieties yielding the Sultana raisins and the Zante grape or "Currant." *Pterisanthes*, a Javan plant, has a very extraordinary structure: its numerous barren and fertile flowers are developed on a very large foliaceous peduncle having the form of a number of divergent plates set edgewise at the end of a long slender stalk; the fertile flowers and berries are sessile on both surfaces of the laminæ, the edges being fringed with stalked barren flowers. The separation of the petals at their bases, remaining coherent above so as to form little 5-rayed stars, is worthy of notice in this Order. The species of *Ampelopsis*, known as "Virginia Creepers," exhibit some interesting phenomena, viz. the assumption of a crimson colour by the foliage in autumn, and the adaptation of their tendrils to form organs of attachment to walls: the points of the tendrils insinuate themselves into little holes and cracks, especially in brickwork, and then expand inside the cavities so as to fix themselves as the stonemasons fix their "lewis," or key, into large blocks of stone.

**Distribution.**—The genus *Vitis,* including *Ampelopsis* and *Cissus,* contains a large number of species, natives for the most part of tropical and subtropical regions. The remaining genera have only a very few representatives. The Vine is supposed to be a native of the shores of the Caspian; but it has run wild in South Europe, and is cultivated all over the world where the temperature is not too low or too high: in the last case it runs away to leaf and does not produce fruit. The stems and roots of some of the *Cissi* of the East Indies are infested by the parasitical Rafflesiaceæ and Balanophoraceæ.

**Qualities and Uses.**—The properties of the Vine (*Vitis vinifera*), with its innumerable varieties, are universally known; the Fox-grapes (*Vitis vulpina* and *Labrusca*) of North America have similar properties when cultivated, but are inferior. The berries of the *Cissi* are acrid; some yield a colouring-matter. The sap of the stems and leaves generally of the Order is sour, containing tartaric acid.

## SUBCLASS 2. CALYCIFLORÆ.

Flowers usually with a calyx and corolla; the petals distinct, springing from the calyx; the stamens perigynous or epigynous.

The character of this Subclass, founded on the insertion of the petals and stamens upon the calyx, is very artificial, and it is liable to exception in certain genera of Orders referable here. On the other hand, it is met with exceptionally in Thalamifloral Orders; and many cases occur where the conditions are difficult to ascertain. Moreover it causes the separation of very natural groups of Orders, such as the removal of Anacardiaceæ, which has both hypogynous and perigynous genera, from the Subclass which includes the Rutaceæ, in accordance with the structure of the majority. Bentham and Hooker, apparently with a view to remove some of these anomalies, have proposed a subclass or series which they call Discifloræ, the most important character of which consists in the presence of a large disk or expansion of the receptacle attached to the calyx or to the ovary, and from which the petals and stamens spring; it thus includes some Thalamifloral and some Calycifloral Orders. The separation of the Perigynous from the Epigynous Orders is rendered impracticable by the occurrence of the two conditions in one Order, as in Rosaceæ.

### ORDER LI. CELASTRACEÆ. THE SPINDLE-TREE ORDER.

*Class.* Frangulaceæ, *Endl.* *All.* Rhamnales, *Lindl.* *Coh.* Celastrales, *Benth. et Hook.*

408. *Diagnosis.*—Shrubs with simple, mostly alternate leaves, and with small deciduous stipules; small regular flowers, the 4–5 sepals and petals imbricated in æstivation; stamens as many as the petals and alternate with them, inserted on a disk filling up the bottom of the calyx; seeds mostly arillate, albuminous.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Euonymus, *Tournef.* | Catha, *Forsk.* |
| Celastrus, *Kunth.* | Elæodendron, *Jacq.* |

**Affinities.**—Related to Rhamnaceæ, differing in the imbricated calyx and the stamens alternating with the petals. Aquifoliaceæ, a monopetalous Order, is very nearly allied; but the Celastraceæ appear to have closer relations with some Thalamifloral Orders, such as Malpighiaceæ through Hippocrateaceæ. The fleshy coat of the seed of *Euonymus* is described by Planchon as an *arillode* or false arillus, arising from the margin of the micropyle.

**Distribution.**—A large Order, the species of which are generally diffused, but more abundant outside the tropics.

**Qualities and Uses.**—More or less acrid, with oily seeds. *Euonymus* *europæus*, the common Spindle-tree of our hedges, is used for gunpowder-charcoal. The inner bark of *E. tingens* is used in dyeing; the seeds of *E. europæus* are said to be purgative and emetic. The bark of *Celastrus scandens* has the same properties. *Catha edulis* has stimulant properties, and the leaves are largely used by the Arabs under the name of *Kat*. The drupaceous fruits of *Elæodendron Kubu* are eaten at the Cape of Good Hope.

(STACKHOUSIACEÆ are a small Order of Australian plants intermediate between Celastraceæ and Euphorbiaceæ; their corolla is monopetalous.

HIPPOCRATEACEÆ, which have hypogynous petals and more or less epigynous stamens, are most nearly related to Celastraceæ (with which, indeed, they are combinedby Bentham and Hooker), connecting them with Malpighiaceæ, Aceraceæ, and through *Staphylea* with Sapindaceæ &c. They are chiefly South-American trees or climbing shrubs, some with edible fruit.

CHAILLETIACEÆ is another small Order, usually placed in this neighbourhood, but with obscure affinities. *Chailletia toxicaria* has a poisonous fruit, called Rat's-bane at Sierra Leone.)

## ORDER LII. RHAMNACEÆ. THE BUCKTHORN ORDER.

*Class.* Frangulaceæ, *Endl.* *All.* Rhamnales, *Lindl.* *Coh.* Celastrales, *Benth. et Hook.*

409. *Diagnosis.*—Shrubs or small trees with simple leaves; small and regular flowers (sometimes apetalous); the 4–5 perigynous stamens as many as the valvate sepals, and alternate with them (opposite to the petals when these are present); disk fleshy; berry or pod with one seed in each cell, albuminous, without an aril.

### ILLUSTRATIVE GENERA.

Paliurus, *Tournef.*
Zizyphus, *Tournef.*
Rhamnus, *Juss.*
Hovenia, *Thunb.*
Ceanothus, *L.*
Phylica, *L.*

**Affinities.**—The Rhamnaceæ are clearly distinguished from the Celastraceæ by the position of the stamens before the petals. The calycifloral condition of their stamens, the fleshy disk, and the separate petals indicate great difference from the corollifloral Order Aquifoliaceæ, also formerly associated with them. Brongniart thinks their nearest relations are to the hypogynous Byttneriaceæ and to Euphorbiaceæ. Some of the genera have free, others adherent ovaries.

**Distribution.**—A rather large Order, the species of which are generally diffused.

**Qualities and Uses.**—Some acrid and purgative, some with bitter tonic properties, others with edible fruits. *Rhamnus* includes *R. catharticus*, the Buckthorn, from the berries of which a purgative syrup is made, also the colour termed Sap-green. The dyeing material called French berries consists of the unripe berries of *R. infectorius*, *saxatilis*, and *amygdalinus*. *Zizyphus* has edible fruit, called Jujubes (*Z. vulgaris*, *Z. Jujuba*, &c.).

The charcoal made from the wood of *R. Frangula* is used for gunpowder-making. *Z. Lotus* is supposed by some to be the Lotus of the ancients, although others think this was *Nitraria* (§ 393). The peduncles of *Hovenia dulcis* enlarge into a succulent fruit, eaten in China; other genera also furnish edible berries. The leaves of *Ceanothus americanus* are consumed as New-Jersey Tea, and those of *Sageretia theezans* are used for Tea by the poorer Chinese.

## Order LIII. ANACARDIACEÆ or TEREBINTHACEÆ.

### The Sumach Order.

*Class.* Terebinthinæ, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Sapindales, *Benth. et Hook.*

410. *Diagnosis.*—Trees or shrubs with a resinous or milky acrid juice; dotless alternate leaves, and small, often polygamous, regular flowers; calyx small, usually with 5, sometimes 3–4 or 7 lobes, persistent; petals equal in number to the lobes of the calyx, or wanting; stamens the same number or double or more, inserted on an annular fleshy disk, or coherent and perigynous. Ovary single, or rarely of 5 or 6 carpels, superior (rarely inferior), 1-celled; style 1, or 3 or 4, sometimes none; stigmas twice as many; ovules solitary, on a long funiculus. Fruit indehiscent, commonly drupaceous; seed without albumen.

Illustrative Genera.

Pistacia, *L.*
Schinus, *L.*
Rhus, *L.*
Melanorrhea, *Wall.*
Stagmaria, *Jack.*
Mangifera, *L.*
Semecarpus, *L.*
Spondias, *L.*

**Affinities.**—The prominent differential characters of this Order reside in the solitary ovule, with ventral raphe and inferior micropyle, or dorsal raphe if the micropyle be superior. This Order is related to the Xanthoxylaceæ in many respects, but differs in the structure of the ovary and seed. From the Burseraceæ also it is divided by the same characters, although *Spondias* connects them as regards the fruit; while the same peculiarities relate it on the other hand to certain Connaraceæ, Rosaceæ, and Leguminosæ.

**Distribution.**—A large Order, the species of which are chiefly tropical, diminishing rapidly beyond the tropics.

**Qualities and Uses.**—The resinous juice of these plants is acrid, or violently irritating and poisonous; it often becomes black in drying. Some kinds, however, yield edible, and even valuable fruits. *Anacardium occidentale*, the Cashew-nut, is remarkable for the curious fleshy enlargement of the peduncle supporting the nut; this peduncle is edible, as is also the seed when roasted; but the pericarp contains acrid volatile oil. A gum-resinous juice exudes from the wood, called Gomme d'Acajou, which is used when fresh as a varnish. *Semecarpus Anacardium*, the Marking-nut, *Melanorrhea usitatissima*, *Stagmaria verniciflua*, *Rhus vernix*, &c. are among the plants furnishing varnishes used in the East Indies, China, and Japan for lacquered ware; their juices are white at first, and become black after exposure to the air. Mastic is obtained from *Pistacia atlantica* and *P. Lentiscus*, Scio turpentine from *P. Terebinthus*; the fruit of *Pistacia vera* is the Pistachio-nut, highly valued in Eastern cookery. *Mangifera indica*, with numerous varieties, yields the well-known tropical drupe called the Mango. The Sumachs, species of *Rhus*, are acrid and poisonous, affecting some constitutions more than others, and sometimes producing violent erysipelas when applied to the skin. *R. Toxicodendron* is the Poison-Oak of North America; *R. venenata*, the Poison-Elder or Poison-Sumach. *R. typhina*, *glabra*, and *Coriaria* have acid fruit and astringent bark, used in tanning; *R. Cotinus*, which is sometimes grown in our shrubberies under the name of the Wig-plant, from the hair-like nature of the sterile flower-stalks, yields the dye-wood called Young Fustic; *R. Metopium*, the Hog-gum of Jamaica, a powerful purgative and emetic. *Spondias purpurea* and *S. Mombin* yield succulent fruits eaten in Brazil and the W. Indies under the name of Hog-plums; *S. Cytherea* or *dulcis* affords a delicious fruit in the Society Islands.

(SABIACEÆ are a small Order of East-Indian plants, removed by recent authors from Anacardiaceæ, where they were formerly placed as anomalous forms.)

(CONNARACEÆ form an Order of tropical trees and shrubs, usually placed near Anacardiaceæ, but destitute of resinous juice, and with orthotropous ovules; the fruits are apocarpous and follicular. They are also allied to the Xanthoxylaceæ. The seeds sometimes have an aril; those of some species of *Omphalobium* are edible. The Zebra-wood, used in cabinet-making, is stated by Schomburgk to be the produce of a Guiana species of this genus, *O. Lamberti*, of great size.)

## ORDER LIV. BURSERACEÆ. THE BALSAM ORDER.

*Class.* Terebinthinæ, *Endl.* *All.* Rutales, *Lindl.* *Coh.* Geraniales, *Benth. et Hook.*

411. *Diagnosis.*—Trees or shrubs abounding in balsam or resin, with alternate or opposite compound leaves, sometimes stipulate and dotted; flowers perfect, or sometimes diclinous by abortion; calyx persistent, with 2–5 divisions; petals and stamens perigynous, outside a perigynous disk; ovary 1–5-celled, superior, sessile in or upon the disk; ovules in pairs; micropyle superior; raphe ventral; fruit dry, 1–5-celled, often splitting into valves; seeds exalbuminous; cotyledons plicate, rarely flat.

### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Boswellia, *Roxb.* | Icica, *Aubl.* | Canarium, *L.* |
| Balsamodendron, *Kunth.* | Bursera, *Jacq.* | Amyris, *L.* |

**Affinities.**—The Amyridaceæ, excepting the genus *Amyris* itself, have a many-celled fruit, which forms a link between Anacardiaceæ and Aurantiaceæ; but the shell of the fruit is hard here, and opens by valves. *Amyris* has dotted leaves. The ovules in pairs separate them from Anacardiaceæ. The want of scales to the stamens separates them from Simarubeæ. From Rutals they differ in their exalbuminous embryo. From Aurantiads they differ in the fruit.

**Distribution.**—The Order consists of about 150 species, distributed throughout the tropics of Asia, Africa, and America.

**Qualities and Uses.**—Fragrant resinous juices are the chief characteristics of this Order. *Boswellia floribunda* and *glabra* yield the East-Indian Olibanum or Frankincense; *B. papyrifera* (Abyssinia) yields a similar Olibanum, and has a remarkable inner bark, capable of separation into sheets, which are used as paper. *Balsamodendron Myrrha* yields Gum Myrrh; Balm of Mecca is produced by *Bals. Opobalsamum* and *Bals. gileadense*. *Bals. Mukul* yields Googal, or Bdellium; *B. pubescens* another balsam, almost soluble in water. *Amyris hexandra* and *A. Plumieri* yield Elemi; the wood of *A. balsamifera* is known as Lignum Rhodium; the balsam of *A. toxifera* is poisonous. *Icica Icicariba* yields Brazilian Elemi, *I. Carana* American Balm of Gilead; and other species afford similar products. *Elaphrium tomentosum* supplies one of the kinds of Tacamahaca, *E. elemiferum* Mexican Elemi; and *Canarium commune* furnishes East-Indian or Manilla Elemi. *Bursera paniculata* (Mauritius) is called Bois de Colophane, giving out freely when wounded an oily juice smelling like turpentine; *B. gummifera* yields Chibou resin, *B. acuminata* Resin of Carana; *Hedwigia balsamifera*, Beaume à cochon, used as a substitute for Copaiba. The wood of *Icica altissima* is used for canoes in British Guiana, under the name of Cedar-wood.

## ORDER LV. LEGUMINOSÆ. THE PULSE ORDER.

*Class.* Leguminosæ, *Endl.* *All.* Rosales, *Lindl.* *Coh.* Rosales, *Benth. et Hook.*

412. *Diagnosis.*—Herbs, shrubs, or trees, with irregular, often papilionaceous or regular flowers; stamens 10 or rarely 5, or sometimes indefinite, diadelphous, monadelphous, or distinct; pistil simple, free, becoming a legume or lomentum; seeds exalbuminous; leaves mostly alternate, stipulate, usually compound.

### *Character.*

*Calyx* more or less deeply 5-fid, the odd lobe in front or next the bract; lobes often unequal and variously combined.

*Corolla*: *petals* 5, or 4–0 by suppression, inserted in the bottom of the calyx, papilionaceous (§ 181) or regular; the odd petal, when present, posterior (fig. 356).

*Stamens* definite or indefinite, inserted on the calyx, rarely hypogynous, distinct or coherent in one or two bundles (9+1, fig. 357), or rarely in three; *anthers* opening by chinks or by pores.

*Ovary* usually solitary, simple, of one carpel (very rarely 2 or 5), 1-celled, 1-, 2-, or many-seeded; *style* and *stigma* simple (fig. 358).

*Fruit*: a legume, lomentum, or rarely a drupe; *seeds* attached to the upper (ventral) suture, 1 or many, sometimes with an arillus; embryo without, rarely with albumen, straight, or with the radicle folded on the cotyledons.

Fig. 356.

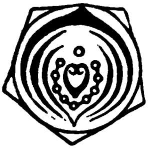


Fig. 357.

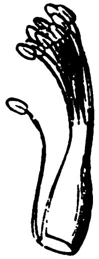


Fig. 358.

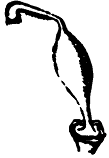


Fig. 356. Ground-plan of a Papilionaceous flower.
Fig. 357. Diadelphous stamens of Leguminosæ.
Fig. 358. Pistil of *Colutea*.

This large Order is divided into three Suborders, which are distinguished by the following characters:—

1. Papilionaceæ. Corolla papilionaceous, imbricated in the bud, with the upper, odd petal exterior.
2. Cæsalpinieæ. Corolla imbricated in æstivation, the odd petal inside the lateral ones.
3. Mimoseæ. Corolla valvate in æstivation.

This vast Order is further subdivided into several tribes, the subdivisions being founded on the degree of cohesion of the stamens, the nature of the pod and cotyledons, the leaves, habit, &c.

### Illustrative Genera.

#### 1. Papilionaceæ.

Chorozema, *Labill.*
Lupinus, *L.*
Ulex, *L.*
Genista, *L.*
Lotus, *L.*
Trifolium, *L.*
Indigofera, *L.*
Glycyrrhiza, *L.*
Astragalus, *L.*
Pisum, *L.*
Vicia, *L.*
Arachis, *L.*
Ornithopus, *L.*
Onobrychis, *Tournef.*
Phaseolus, *L.*
Dalbergia, *L.*
Sophora, *L.*

#### 2. Cæsalpinieæ.

Hæmatoxylon, *L.*
Cæsalpinia, *L.*
Cassia, *L.*
Cathartocarpus, *Pers.*
Swartzia, *Willd.*
Amherstia, *Wall.*
Jonesia, *Roxb.*
Schotia, *Jacq.*
Tamarindus, *L.*
Copaifera, *L.*
Ceratonia, *L.*

### 3. Mimoseæ.

Entada, *L.*
Adenanthera, *L.*
Prosopis, *L.*
Mimosa, *L.*
Acacia, *Willd.*
Inga, *Willd.*

**Affinities, &c.**—This immense Order presents very considerable variety of structure within its wide limits; and but one character is absolutely constant, the position of the sepals; the irregularity of the corolla disappears altogether in the *Mimoseæ*, and the legume is exchanged for a drupe in *Detarium* and *Dipteryx*; this causes a near approach to the Rosaceæ; but it may be noticed that when the flower is regular the fruit is leguminous, and *vice versâ*; and the anterior position of the odd sepal of the calyx is an unexceptional character of this Order. The *Cæsalpinieæ* have the papilionaceous exchanged for a spreading irregular form, or the petals are suppressed. In *Mimoseæ* the stamens are hypogynous. The last fact brings the Order closely into relation with the Anacardiaceæ, from which it is not easy to distinguish some of the apetalous *Cæsalpinieæ* at first sight.

The single carpel in the ovary of this Order is almost a universal character; two carpels, however, appear to be normally present in *Diphaca* and *Cæsalpinia digyna*; a double ovary sometimes occurs as a monstrosity in *Wistaria sinensis*, in *Gleditschia*, and in the French bean (*Phaseolus*); and a *Mimosa* with 5 carpels (thus a symmetrical flower) is said to have been seen by St.-Hilaire. The simple legume presents a great variety of conditions, both of form, consistence, and dehiscence. Its normal form is such as we see in the garden Pea (fig. 359); in *Colutea* (the Bladder-Senna) it is inflated and membranous; in *Astragalus* the dorsal suture turns in and forms a false septum (fig. 362); in *Phaca* it is spongy or fleshy; in many cases it is woody; it may be straight, or curved, or even spirally curled (*Medicago*, fig. 361); in the lomentaceous form it is constricted at intervals, often breaking into 1-seeded joints (fig. 360); in *Cathartocarpus*

Fig. 359.

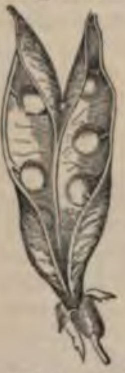


Fig. 359. Legume of *Pisum*.

Fig. 361.

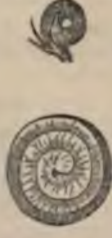


Fig. 361. Legumes of *Medicago*.

Fig. 362.

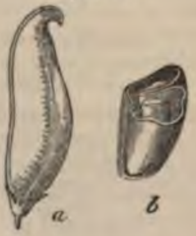


Fig. 362. Legume of *Astragalus*: *a*, entire; *b*, cut across.

Fig. 360.

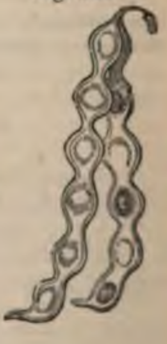
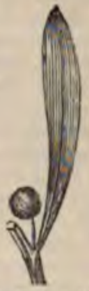


Fig. 360. Lomentum of *Acacia*.

it is cylindrical; in *Detarium* and *Dipteryx* the 1-seeded ovary developes a bony endocarp and fleshy epicarp, and becomes a drupe, like the Almond. The dehiscence is equally varied: normally both sutures open and the valves separate; in *Hæmatoxylon* the valves adhere at the sutures and split in the middle. In *Carmichaelia* the valves separate from the suture; in *Ornithopus* &c. the lomentum breaks up, and the pieces either open or remain indehiscent; in *Entada* the lomentaceous pod is opened by the valves separating in pieces. In *Cathartocarpus*, *Arachis*, *Tamarindus*, and other cases no dehiscence occurs at all; and in *Cathartocarpus* and *Tamarindus* a pulp is formed inside the legume.

The irritability of the leaves of many Leguminous plants is a striking characteristic: it is most remarkable in the *Hedysareæ*, as in *Smithia*, *Desmodium*, &c., and in *Mimosa*; but it exists in a lower degree very commonly, even in the Locust-tree (*Robinia Pseudo-acacia*). The Acacias are noticeable for the phyllodial petioles, which often wholly replace the leaves (fig. 363).

Fig. 363.



Phyllode, with axillary head of flowers of *Acacia*.

**Distribution.**—The Order comprises nearly 7000 species. The *Papilionaceæ* are universally distributed, but are most abundant in warm climates; some genera are widely diffused, others almost confined to particular parts of the globe, as Australia, North or South America, Cape of Good Hope, &c. The *Cæsalpinieæ* and *Mimoseæ* are chiefly tropical; but the latter abound beyond this limit in Australia.

**Qualities and Uses.**—This Order contains a vast number of plants; and among them there is an exceeding diversity of properties. Those with mild juices are frequently exceedingly nutritious; when the juices are more concentrated, they become either purgative or astringent, and some of them poisonous; the poisonous properties occur in all parts, but chiefly in the seeds and bark. In other respects, they furnish most valuable timber, fibres, gums, dyes, &c. In enumerating some of the most important plants, it will be best to take them under the heads of the Suborders.

1. *Papilionaceæ*.—A large proportion of the common fodder-plants, such as Clover (*Trifolium*), Lucern and Medic (*Medicago*), *Melilotus*, Sainfoin (*Onobrychis*), &c., belong to this Suborder; and various other similar plants are in use in foreign countries, such as species of *Astragalus*, *Crotalaria juncea*, *Desmodium diffusum*, *Indigofera enneaphylla*, &c. The seeds of many species are eaten, constituting the various kinds of pulse; such as Broad Beans (*Faba*), Haricots and Scarlet Beans (*Phaseolus*), Peas (*Pisum*, *Dolichos*), Lentils (*Ervum*, *Vicia*), Chick-peas (*Cicer*), Pigeon-peas (*Cajanus*), Lupines, &c. The roots of some of these are said to be poisonous, as those of *Phaseolus*; but, as is well known, the pericarps or pods are eaten boiled in the young state. Saccharine matter exists in the roots of Liquorice (*Glycyrrhiza glabra*, with *G. echinata* and *glandulifera*); a kind of Manna is obtained from the Camel-thorn (*Alhagi Maurorum*); *Astragalus glycyphyllus* has a sweet juice. The tuberous roots of *Dolichos tuberosus* and *bulbosus*, *Apios*, *Pueraria*, and *Lathyrus tuberosus* are eaten in the same way as potatoes.

Among the purgative species are Bladder-Senna (*Colutea arborescens*), the leaflets of which are often used to adulterate true Senna, and *Coronilla Emerus* and *C. varia*: the last is reputed to be poisonous; various species of *Genista, Cytisus, Robinia,* &c. are diuretic and cathartic.

The well-known astringent substance Kino is obtained in Africa from *Pterocarpus erinaceus,* in the East Indies from *P. Marsupium,* Gum Dragon from *P. Draco,* and Red Sandal-wood from *P. santalinus.* A somewhat similar substance to Kino is obtained in the East Indies from the Dahk trees (*Butea frondosa* and *superba*). *Erythrina monosperma* yields Gum Lac. A few plants of this Suborder yield gums, such as Tragacanth, from *Astragalus verus, creticus, cristatus, gummifer,* and *strobiliferus.*

Dyes are obtained from many, as Indigo from *Indigofera tinctoria, cærulea, argentea,* and probably others, and from *Tephrosia Apollinea* and other species; *Baptisia tinctoria* gives an inferior kind. The flowers of the *Buteæ* give a brilliant orange-yellow colour; *Sophora japonica* furnishes yellow from the pulp of its pods; Dyer's broom (*Genista tinctoria*) gives a good yellow colour, and forms a green with *Isatis.*

Ornamental and useful timber is afforded by some, as Rose-wood (*Palissandre* of the French) from various Brazilian species of *Triptolomea,* Itaka-wood of Guiana (*Machærium Schomburgki*), Laburnum-wood (*Cytisus Laburnum*), Locust (*Robinia Pseudo-acacia*); *Dalbergia Sissoo* and other species, and *Pterocarpus dalbergioides,* are highly valued in the East Indies. Others furnish fibrous substances, such as *Crotalaria juncea,* yielding Bengal Hemp.

*Dipteryx odorata* (Tonka-bean) and *D. oleifera* (Eboe-nut) are used in perfumery. The hairs from the pods of Cowhage (*Mucuna pruriens*) were formerly used as an anthelmintic. The seeds of *Astragalus bæticus* are used as a substitute for and adulteration of coffee in Germany.

The distinctly poisonous plants of this Suborder are numerous. The roots of the Scarlet-runner bean (*Phaseolus multiflorus*) and other species are narcotic poisons; also the seeds of Laburnum (*Cytisus Laburnum, alpinus,* &c.), those of *Lathyrus Aphaca,* and, it is said (but denied by others), those of *Abrus precatorius* (the scarlet seeds with a black patch, often used as beads), *Anagyris fœtida, Ervum Ervilia,* &c. Indigo is a violent poison; the shoots of various kinds of *Tephrosia,* especially *T. toxifera,* are used to poison fish, as is the bark of *Piscidia Erythrina,* a powerful narcotic. Species of *Geoffroya,* as *G. vermifuga* and *spinulosa,* and *Andira inermis* and *retusa,* having drastic purgative and emetic barks, are acrid-narcotic poisons in large doses. *Gompholobium,* an Australian genus, is said to poison sheep. *Physostigma venenosum* furnishes the poisonous Calabar bean used as an ordeal by the natives, and in medicine for its use in contracting the pupil of the eye. It acts as a powerful nervous sedative.

2. *Cæsalpinieæ.*—This Suborder does not appear to have any decidedly poisonous properties; but a purgative quality is very common, as in Senna, *Cassia obovata, Senna, acutifolia,* and *lanceolata*; *C. marilandica* and other North-American species have similar properties. *Cassia* or *Cathartocarpus Fistula* has a purgative fruit; and the pulp of the Tamarind (*Tamarindus indica*) shares this quality. Besides the Tamarind, other fruits, less acid, are eaten, as the Tamarind Plum (*Dialium indicum*) and the Tamarinds of Sierra Leone, which are species of *Codarium.* Carobs or Algarobas, the legumes of *Ceratonia Siliqua* (also called St. John's, or the Locust-tree), are

used for feeding horses in Spain, and have recently been imported for feeding stock in this country. *Gleditschia triacanthos* bears a similar fruit, called in North America the Honey-locust; the fruit of the West-Indian Locust, *Hymenæa Courbaril*, is somewhat similar, but is said to purge when fresh gathered; a kind of beer is made from it by decoction and fermentation.—Many *Cæsalpinieæ* have bitter and astringent properties, and are sometimes used in medicine, several of them in tanning and dyeing, as Divi divi, the pods of *Cæsalpinia Coriaria*, one of the most powerful of known astringents; the bark of some species of *Bauhinia* and *Cassia* are used in similar ways.—The dye-woods are important, namely Logwood (*Hæmatoxylon campechianum*), Brazil-wood or Pernambuco-wood (*Cæsalpinia echinata, brasiliensis*, and other species), Cam-wood or Barwood (*Baphia nitida*), &c. The West-Indian Locust-tree (*Hymenæa Courbaril*), the Purple-heart of Guiana (*Copaifera pubiflora* and *bracteata*), *Melanoxylon Brauena, Eperua falcata*, &c. yield very hard and durable timber. The size of some of the Cæsalpineous trees of the South-American forests is said to be enormous, as much as 84 feet in circumference at the base, where large projecting buttresses occur, and 60 feet at the commencement of the clear run of the trunk.

The bark of *Bauhinia racemosa* and *parviflora* is used for cordage in the East Indies. Gum is yielded by several, as *Bauhinia retusa* and *emarginata* in the East Indies, and *Pithecolobium gummiferum* in Brazil. Anime resin is obtained from *Hymenæa Courbaril*; Mexican Copal probably from an allied plant; Brazilian Copal from various species of this genus, and from *Trachylobium Martianum*; Madagascar Copal, and perhaps that of the East Indies in general, from *Hymenæa verrucosa*. Balsam of Copaiba is derived from various West-Indian and Brazilian species of *Copaifera*; Balsam of Peru from *Myroxylon Pereiræ*; Balsam of Tolu from *M. toluiferum*. *Aloëxylum Agallochum* yields one kind of Eagle- or Aloes-wood, the other coming from an *Aquilaria*.

3. *Mimoseæ*.—Mucilaginous juices concreting into gum and astringent properties of the bark are the most striking qualities of this Suborder. Gum Acacia and its varieties are yielded by several species of *Acacia*:—*A. Verek* and *Adansonii* (Gum Senegal) in West Africa, *A. nilotica* and *Seyal* (Gum Arabic) in Nubia, *A. arabica, spinosa*, and (*Vachellia*) *Farnesiana* in the East Indies, *A. decurrens, mollissima* and *affinis* in Australia. The bark of most species of *Acacia* is very astringent, and many kinds are used for tanning in India; the pods of *A. nilotica* are used for the same purpose; and the astringent substance called Catechu is obtained by extraction with water from the heart-wood of *Acacia Catechu*. Various species of *Inga, Prosopis*, &c. are very astringent. Some East-Indian Acacias yield valuable timber; the legumes of *A. concinna* and the large seeds of *Entada Pursætha* contain a saponifying substance. Some kinds of *Mimosa* and *Prosopis* are said to have poisonous properties. *Acacia varians*, of Australia, has been called the Poison-tree. It is hardly necessary to add that a great number of plants from all these Suborders are cultivated for the sake of their beautiful flowers.

(MORINGACEÆ form a very anomalous group of 3 or 4 species only, marked by the following characters:—Trees with 2–3-pinnate leaves and thin deciduous stipules; flowers irregular, 5-merous; sepals and petals petaloid; stamens 8–10 on a disk in the tube of the calyx, the outer circle sometimes sterile; anthers 1-celled; ovary superior, stalked, 1-celled with 3 parietal many-ovuled placentas; fruit a long 3-valved pod with the seeds in the middle of the valves; seeds without albumen. The species are natives of Arabia and the East Indies, and have generally been referred to the vicinity of the Leguminosæ, principally on account of their perigynous irregular flowers, pinnate leaves, and pod-like fruits. The structure of the ovary removes them widely from Leguminosæ, on account of the parietal placentation, since, judging from Rosaceæ, the occurrence of additional carpels in Leguminosæ would be accompanied by an apocarpous condition, or at least axile placentas. *Diphaca* and *Cæsalpinia digyna* (Leguminosæ) are in fact described as having 2 legumes; but the monstrous forms of *Gleditschia* referred to by De Candolle are said to have 2 coalescent carpels. Hence Lindley places this Order in the neighbourhood of Violaceæ, and conceives that it approaches Polygalaceæ. Others place it between Capparids and Resedaceæ, to the former of which Orders it is certainly closely allied. The root of *Moringa pterygosperma* is pungent and aromatic, resembling Horse-radish. A gum like Tragacanth exudes from the bark. The seeds are the Ben-nuts; and the oil of Ben was formerly highly esteemed for perfumery, and for lubricating watchwork, on account of its comparative freedom from easily-solidifying fatty ingredients.)

## ORDER LVI. ROSACEÆ. THE ROSE ORDER.

*Class.* Rosifloræ, *Endl.* *All.* Rosales, *Lindl.* *Coh.* Rosales, *Benth. et Hook.*

413. *Diagnosis.*—Herbs, shrubs, or trees with regular flowers; numerous (rarely few) distinct stamens inserted on the calyx; carpels 1 or many, either quite distinct or coherent, and enclosed in the tube of the receptacle; seeds (anatropous) 1 or few in each ovary, exalbuminous; embryo straight, with large and thick cotyledons; leaves alternate, stipulate.

### *Character.*

*Calyx* monosepalous, with 4–5 lobes, the odd lobe posterior, *i. e.* next the axis, when 5; sometimes with an *epicalyx.*

*Corolla*: *petals* 5, distinct, inserted on the calyx, rarely absent.

*Stamens* definite or indefinite, inserted with the petals.

*Ovaries* apocarpous, 1–2, or 5 or numerous, 1-celled, sometimes combined together in the excavated receptacle (fig. 364) or tube of the calyx; *ovules* 1 or few; *styles* lateral (fig. 367) or terminal.

*Fruit*: a drupe, an achene, or a dry or succulent etærio (figs. 365, 366), or a cynarrhodon or a pome (fig. 368); *seeds* 1 or more, exalbuminous; *embryo* straight.

This Order is commonly broken up into several smaller Orders, which we shall characterize here as Suborders.

1. **Chrysobalaneæ.** Trees or shrubs with free stipules; carpel 1, adherent more or less to one side of the calyx; ovules 2; style basilar; fruit a drupe; seed erect.

2. **Drupaceæ** or **Pruneæ.** Trees or shrubs with free stipules; carpel 1, free; style terminal; fruit a drupe, not enclosed in the tube of the flower, which is deciduous; seeds suspended.

3. **Pomeæ.** Trees or shrubs with free stipules; carpels 1–5, more or less united together and with the sides of the flower-tube; styles terminal; fruit a pome, 1–5-celled or spuriously 10-celled, with a crustaceous *core* or bony *stones* (fig. 365); seeds ascending.

4. **Roseæ.** Shrubs or herbs with adnate stipules; carpels free from the calyx, 1 or many, 1-celled, sometimes cohering; styles lateral; fruit usually etærios formed of an assemblage of dry achenes, small drupes, or dehiscent several-seeded follicles; seed suspended, rarely ascending.

5. **Sanguisorbeæ.** Herbs or undershrubs, apetalous, often diclinous; carpel 1; style from the summit or base; fruit an achene, surrounded by the persistent tube of the calyx; seed 1, suspended or ascending.

Fig. 364.

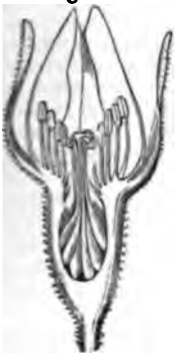


Fig. 365.

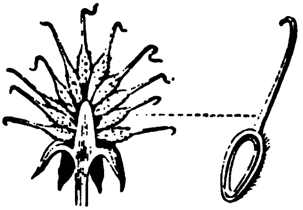


Fig. 368.

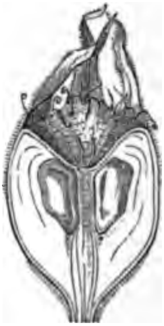


Fig. 366.

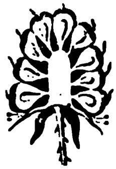


Fig. 367.

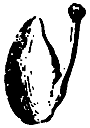


Fig. 364. Section of the flower of *Rosa*.
Fig. 365. Dry etærio of *Geum*.
Fig. 366. Section of succulent etærio of *Rubus*.
Fig. 367. Ovary of *Fragaria* with lateral style.
Fig. 368. Section of the pome of *Mespilus*.

ILLUSTRATIVE GENERA.

I. CHRYSOBALANEÆ.
Chrysobalanus, *L.*

II. AMYGDALEÆ, or DRUPACEÆ.
Prunus, *L.*

III. POMEÆ.
Pyrus, *Lindl.*
Cratægus, *L.*

IV. ROSEÆ.

1. ROSIDÆ. *Flower-tube fleshy, enclosing the achenes.*
Rosa, *Tournef.*

2. POTENTILLIDÆ. *Flower-tube herbaceous; fruit an etærio.*
Rubus, *L.*
Fragaria, *L.*
Potentilla, *L.*

3. SPIRÆIDÆ. *Flower-tube herbaceous; fruit a ring of follicles; seeds not winged.*
Spiræa, *L.*

4. QUILLAIÆ. *Flower-tube herbaceous; fruit capsular; seed winged.*
Quillaia, *Mol.*

5. NEURADEÆ. *Calyx adhering to a ring of* 10 *carpels; seed pendulous.*
Neurada, *L.*

V. SANGUISORBEÆ.
Alchemilla, *Tournef.*
Poterium, *L.*

**Affinities.**—Closely allied to Leguminosæ; and, indeed, the only constant point of difference consists in the position of the odd sepal—posterior in Rosaceæ, anterior in Leguminosæ. The *Chrysobalaneæ* may be regarded as forming a link between the Leguminosæ and the *Drupaceæ*, touching that Order especially in its drupaceous genera and those with a laterally adherent calyx. The *Drupaceæ* have some affinity also to Anacardiaceæ; *Pomeæ* again connect the Order with the epigynous families, especially Myrtaceæ, through *Punica*. *Roseæ* resemble *Pomeæ* in many respects, but their affinities go out in other directions; Calycanthaceæ should, perhaps, scarcely be separated from them. The *Spiræidæ* very much resemble some Saxifragaceæ (distinguishable by their albuminous seeds); and the *Potentillidæ* remind us of the Ranunculaceæ in the fruit and the adnate stipules, which sometimes closely approach the dilated base of the petiole of *Ranunculus* &c.; but Ranunculaceæ have albumen and usually hypogynous stamens, though the difference in some genera between hypogynous and perigynous position of the stamens is almost imperceptible. *Sanguisorbeæ* are merely a degraded form of *Roseæ*, where the petals and one or other set of essential organs are abortive in each flower.

**Distribution.**—There are about a thousand species. The *Chrysobalaneæ* are chiefly found in tropical America and Africa, more rarely in Asia; the *Drupaceæ* are mostly natives of the temperate parts of the Northern Hemisphere, but are widely spread in cultivation; the *Pomeæ* also belong to the Northern Hemisphere; most of the *Roseæ* and *Sanguisorbeæ* belong to temperate and cold climates, but a few are tropical.

**Qualities and Uses.**—The succulent fruits of many of the plants form the most striking feature of this Order. Various parts of the structure, but especially the seeds, yield much hydrocyanic acid in the Suborders *Drupaceæ* and *Pomeæ*. The bark and root of almost all are bitter and astringent, owing to the presence of tannin. *Drupaceæ* commonly contain a gum (resembling Gum Arabic) in the sap. This gum is the result of a pathological change in the tissues.

Most of the *Chrysobalaneæ* have stone-fruits; that of *C. Icaco* (West Indies) is eaten under the name of Cocoa-plum.

Among the *Drupaceæ* we have the fruits:—Almond (*Amygdalus communis*); the Peach and Nectarine (*A. persica*); the Plum in all its varieties, such as Greengages, Bullaces, Damsons, &c. (*Prunus domestica, spinosa,* and varieties); the Apricot (*Prunus armeniaca*); the Cherry (*Cerasus avium*, &c.). *Cerasus Lauro-cerasus* is the common "Laurel," or Cherry-laurel of our shrubberies, *C. lusitanica* the Portugal Laurel. Many of these plants contain a considerable quantity of *amygdaline*, causing the formation of prussic acid when they are bruised. This gives to the seeds of the Bitter variety of Almond, and to all other seeds in this Suborder, a poisonous property, which exists also to a great extent in the leaves and shoots of the Cherry-laurel, the flowers of the Almond, Peach, &c. The seeds also contain a fixed oil, which may be obtained by expression; and that of the Sweet variety of the Almond is devoid of *amygdaline*, and thus harmless. *Pomeæ* have succulent fruits, such as the Apple, Pear (*Pyrus Malus* and *communis*), Quince (*Cydonia vulgaris*), Medlar (*Mespilus germanica*), &c., which have been brought into the edible condition by cultivation; when wild, they are mostly austere, like those of the Hawthorn (*Cratægus*), of the Mountain Ash (*Pyrus Aucuparia*), &c. The seeds contain amygdaline, and therefore yield prussic acid; as do also the flowers, bark, and root of the Mountain Ash. Quince-seeds are valuable for the mucilage they contain. The *Roseæ* yield edible fruits, such as the Raspberry and Blackberry (*Rubus idæus* and *fruticosus*) and the Strawberry (*Fragaria elatior*, *vesca*, &c.). The petals of Roses yield the essential oil called Otto or Attar of Roses. Kousso (*Brayera anthelmintica*) is used as a vermifuge. Most of the *Roseæ* have astringent bark and roots; some are unwholesome. *Sanguisorbeæ* have astringent properties similar to *Roseæ*. *Quillaiæ* contain in their bark a saponaceous principle, which renders them useful for cleaning silk fabrics.

(CALYCANTHACEÆ form a small Order, consisting of shrubs with opposite entire leaves, without stipules; sepals and petals similar and indefinite; anthers adnate and extrorse; cotyledons convolute; otherwise like Rosaceæ. The species are natives of North America and Japan, and are chiefly remarkable for the peculiarity of their floral envelopes, the coloured bracts of the peduncle passing insensibly or undistinguishably into the calyx, and this into the corolla; the segments of both are inserted on a fleshy tube supporting the stamens and surrounding the carpels; convoluted cotyledons are only found in one Rosaceous plant, *Chamæmeles* (*Pomeæ*), but are characteristic of Combretaceæ. Calycanths stand between the Rosaceæ and the Myrtaceæ, and have, perhaps, a distant resemblance to Magnoliaceæ, like that of Rosaceæ to Ranunculaceæ. Baillon places them with Monimiads. Their wood is curious, the stem having four false woody axes around the real axis, giving the stem a quadrangular character. The chief property is fragrance of the blossom. *Chimonanthus* produces yellow flowers upon the leafless branches during the winter. *Calycanthus floridus* has an aromatic bark.)

## ORDER LVII. MYRTACEÆ. THE MYRTLE ORDER.

*Class.* Myrtifloræ, *Endl.* *All.* Myrtales, *Lindl.* *Coh.* Myrtales, *Benth. et Hook.*

414. *Diagnosis.*—Trees or shrubs with leaves opposite or alternate, entire, usually dotted, and with a submarginal vein; flowers usually

xillary, polypetalous or apetalous; calyx adherent, 4–5-cleft, valvate or imbricate, sometimes falling off like a cap; petals 4–5, imbricated; stamens 8–10 or numerous, rarely 4–5, distinct or polyadelphous; ovary 1-, 2-, 4-, 5-, or 6-celled; style and stigma simple; placentas axile; seeds usually indefinite, exalbuminous; fruit dry or succulent, dehiscent or indehiscent.

ILLUSTRATIVE GENERA.

| Tribe 1. LEPTOSPERMEÆ. *Fruit capsular.* | Tribe 2. MYRTEÆ. *Fruit baccate.* |
|---|---|
| Melaleuca, *L.* | Punica, *L.* |
| Eucalyptus, *Hérit.* | Psidium, *L.* |
| Metrosideros, *R. Br.* | Myrtus, *Tournef.* |
| Bæckia, *L.* | Eugenia, *Michel.* |

**Affinities.**—This Order is nearly related to the Rosaceæ on the one hand, and to the Melastomaceæ, Lythraceæ, and Onagraceæ on the other. The Lecythidaceæ, the Chamælauciaceæ, and some other smaller Orders mentioned below are often combined with the Myrtaceæ; but as the plants belonging to them are less interesting, or less frequently seen, it is convenient here to exclude them, in order to retain a very definite character for the Myrtaceæ proper. This Order is generally known among epigynous forms by the vein running round within the margin of the simple, entire, and mostly opposite leaves, uniting with the midrib at the end, together with the transparent glandular dots and the absence of stipules and of appendages to the anthers. The fruit of *Punica* is very curious, and presents unusual conditions—a double circle of carpels, which by the mode of growth of the excavated receptacle come to be placed one above another, so as to present two tiers of loculi in the fruit. The real nature of the structure may be conceived by comparing it with the Rose, and by supposing the achenes of the latter to become enlarged loculi containing pulp. Bentham and Hooker put this genus into Lythraceæ; but its affinities seem rather with Myrtles, of which it forms an anomalous genus.

**Distribution.**—A large Order, the members of which are distributed throughout tropical and subtropical climates.

**Qualities and Uses.**—Generally aromatic from the presence of a volatile oil, some astringent, and others yielding gums or saccharine juices. The *Myrteæ* are remarkable for their aromatic properties: thus *Caryophyllus aromaticus* furnishes the Cloves used for spice, consisting of the dried unopened flower-buds; *Eugenia Pimenta* and *E. acris* Allspice or Pimento, consisting of the dried fruits: the buds and berries of the common Myrtl were used in a similar manner by the ancients. This tribe also afford excellent fruits: the Guavas are yielded by species of *Psidium*, chief *pomiferum* and *pyriferum*; the Rose-apples by *Eugenia malaccensis*, *Jamb aquea*, &c.; the Pomegranate, *Punica Granatum*, the rind of which is a valuable for its astringent properties, which cause it to be used b medicinally and for tanning. Among the *Leptospermeæ*, the Caje *Melaleuca Cajeputi*, is well known for its acrid volatile oil, obtained distillation from the leaves. *Metrosideros* is a genus some of the sp of which form very striking features in the vegetation of New Zea

*M. buxifolia* and other species, called Aki, Rata, &c., overgrowing trees, like the *Ficus indica*, and themselves ultimately becoming exceedingly hard-wooded trees. The *Eucalypti* of Australia are still more remarkable in many respects: some of them attain a height of 200 feet or more, and a diameter of 10 to 15, rising to 100 or 150 feet clear of branches. The bark of some of them separates in fibrous layers, whence they have derived the common name of Stringy-barks. They are also called Gum-trees, from containing a gummy or saccharine sap, occasionally of astringent character. *E. robusta* secretes a red gum in the interior of the trunk; from *E. mannifera* a saccharine substance like manna is obtained. *E. Gunnii* yields, when tapped, a sweet fluid, which is fermented into a kind of beer. *E. resinifera* furnishes an astringent substance known as Botany-Bay Kino. Other species also contain a sufficient quantity of tannin to be of commercial importance. The leaves of some species of *Leptospermum* and *Melaleuca* are used for Tea in the Australian colonies.

Many of the Myrtaceæ are cultivated on account of their beauty. The common Myrtle, a native of Persia, naturalized in Southern Europe, bears our winters, and flowers out of doors in the south-west of England. It affords many beautiful varieties in cultivation. The species of *Metrosideros*, *Callistemon*, &c., sometimes called Bottle-brush plants, have very curious and showy blossoms. The Pomegranate flowers and fruits in sheltered places, and bears a very brilliant blossom.

(LECYTHIDACEÆ are chiefly distinguished from the Myrtaceæ (with which they are united by Bentham) by the dotless foliage and the hood-like petaloid plate, consisting of concrete stamens, covering the middle of the flower. The species are usually large trees; their fruit is very remarkable, consisting of a large woody case, the top of which sometimes separates like a lid (*Lecythis*), whence they have been called Monkey-pots. They are chiefly found in Guiana and Brazil. The Brazil-nuts of commerce are the seeds of *Bertholletia excelsa*, and are formed inside a large round woody seed-vessel. *Couroupita guianensis*, the Cannon-ball tree, yields a fruit containing a pulp agreeable when fresh; the shells, like the "pots" of *Lecythis*, are used for domestic purposes. The bark of *Lecythis Ollaria* and other species is separable into fine papery layers, used for wrapping cigars. *L. Ollaria* is one of the giants of the Brazilian forests; its seeds are called Sapucaya-nuts.)

(BARRINGTONIACEÆ are a small Order of tropical trees and shrubs, placed by most authors among or near the Myrtaceæ: their foliage agrees rather with that of Lecythidaceæ, although without stipules; but their flowers are destitute of the hood. The structure of their seeds has been misunderstood: they are destitute of albumen, and consist chiefly of a large axis with minute cotyledons. They appear to have dangerous qualities. Humboldt and Bonpland relate that when the fruit of *Gustavia speciosa* is eaten by children their skin becomes yellow, but the discoloration disappears in a day or two without any treatment. *Barringtonia* and *Gustavia* are met with in cultivation as large and showy stove-shrubs.)

(CHAMÆLAUCIACEÆ are a group of Australian shrubs, of heath-like aspect, distinguished from Myrtaceæ proper chiefly by the fringe of scales or bristles which frequently surrounds the tube of the calyx (whence the name of Fringe-myrtles), and by the 1-celled (rarely 2-seeded) ovary. They have no known utility. Genera: *Chamælaucium*, Desf.; *Darwinia*, Rudge; *Calytrix*, Labill. Some of the species are very ornamental as greenhouse plants, as the *Darwinias* (*Hedaroma*) &c.)

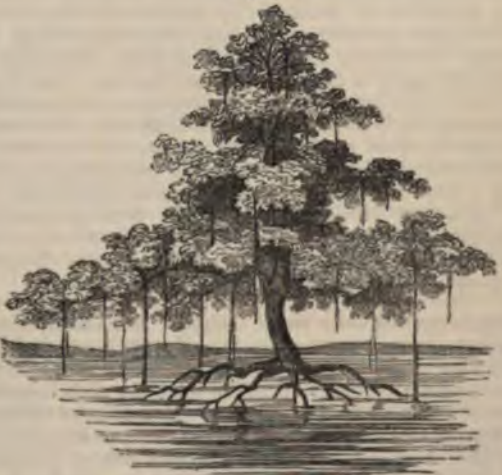
(BELVISIACEÆ consist of a few species of handsome shrubs, belonging to the genera *Napoleona*, Palis., and *Asteranthos*, Desf., formerly supposed to be related to Cucurbitaceæ and Passifloraceæ, but apparently only forms of Myrtaceæ remarkable for the several concentric gamopetalous circles of the corolla (or corona), the polyadelphous stamens, and flat stigma. *Napoleona imperialis* forms a large fruit, with an edible pulp and a rind containing much tannin. The structure of the flower is curious and interesting. They are natives of tropical Africa and Brazil.)

## ORDER LVIII. RHIZOPHORACEÆ. MANGROVES.

*Class.* Calycifloræ, *Endl.* *All.* Myrtales, *Lindl.* *Coh.* Myrtales, *Benth. et Hook.*

415. *Diagnosis.*—Trees or shrubs growing on muddy sea-shores (fig. 369), with opposite leaves and deciduous convolute interpetiolar stipules; flowers with an adherent calyx, 4–12-lobed, the lobes sometimes coherent, valvate; petals equal to the calyx-lobes in number, springing from the calyx; stamens perigynous, twice or thrice as many as the petals; ovary 2-, 3-, or 4-celled, each cell with 2 or more pendulous ovules; fruit 1-seeded, crowned by the calyx; seeds exalbuminous, germinating and forming a very long root before the fruit falls from the tree.

Fig. 369.



ILLUSTRATIVE GENERA.

Rhizophora, *Lam.* | Bruguiera, *Lam.*

**Affinities, &c.**—This small but interesting Order consists of about 20 species, of very distinct habit, but somewhat complicated in their affinities, agreeing with the Myrtaceæ, Melastomaceæ, Vochysiaceæ, and Combretaceæ in many respects, while there is a relation with Lythraceæ, Cunoniaceæ, &c. in others; Endlicher, as well as Bentham and Hooker, place here *Cassipourea* and *Legnotis*, which connect this Order with the last two; Lindley refers the *Cassipoureæ* or *Legnotidæ* to the Loganial Alliance.

The striking feature of this Order is the germination of the seeds within the fruit while still attached, the roots usually descending to the mud and establishing themselves before the plumule emerges. The trees also continually send out arching adventitious roots, which strike and become new trunks, like those of the *Ficus indica*, forming the Mangrove-swamps of tropical estuaries. The fruit of *Rhizophora Mangle* is edible. The bark is generally very astringent in this family. The wood of the radicles contains curiously branched wood- or liber-cells.

## ORDER LIX. VOCHYSIACEÆ.

*Class.* Calycifloræ, *Endl.* *All.* Sapindales, *Lindl.* *Coh.* Polygalinæ, *Benth. et Hook.*

416. *Diagnosis.*—Trees or shrubs, with resinous juice and mostly opposite entire leaves, with glands or stipules at the base; flowers perfect, irregular; calyx and corolla imbricated, of unequal pieces; stamens 1–5, usually opposite the petals, arising from the bottom of the calyx, mostly only one fertile, with an ovate 4-celled anther; ovary free, or partly adherent, 3-celled, with axile placentas, or 1-celled with 2 basilar ovules; seeds usually winged, without albumen.

ILLUSTRATIVE GENERA.

Qualea, *Aubl.* | Vochysia, *Juss.* | Salvertia, *St.-Hil.*

**Affinities, &c.**—A small Order, the members of which are natives of the equinoctial regions of America, and are known chiefly as timber-trees, often with large showy blossoms. Their affinities are obscure. Some authors regard them as related to the Clusiaceæ, others to the Violaceæ and the Polygalaceæ, near which latter they are placed by Bentham and Hooker. On account of their calycifloral structure they are usually placed near Combretaceæ.

## ORDER LX. COMBRETACEÆ.

*Class.* Calycifloræ, *Endl.* *All.* Myrtales, *Lindl.* *Coh.* Myrtales, *Benth. et Hook.*

417. *Diagnosis.*—Trees or shrubs, with alternate or opposite, exstipulate leaves, not dotted; flowers perfect or diclinous by abortion; calyx adhe-

rent, with a 4–5-lobed deciduous limb; petals 5, calyciflorous, or absent; stamens perigynous, 5, 10, or 15, mostly 10; ovary 1-celled, with 2–4 pendulous ovules; style and stigma simple; seeds exalbuminous; cotyledons convolute.

### ILLUSTRATIVE GENERA.

Tribe 1. TERMINALIEÆ. *Usually apetalous; cotyledons convolute.*

Bucida, *L.*
Terminalia, *L.*
Pentaptera, *Roxb.*

Tribe 2. COMBRETEÆ. *Corolla present; cotyledons plaited.*

Combretum, *Löffl.*
Quisqualis, *Rumph.*

Tribe 3. GYROCARPEÆ. *Apetalous; cotyledons convolute; anthers bursting by recurved valves.*

Gyrocarpus, *Jacq.*
Illigera, *Bl.*

**Affinities.**—Related to Myrtaceæ, especially through *Punica*, but distinguished clearly by the unilocular ovary and 1-seeded fruit. The structure of the flower allies the Order to Onagraceæ and Rhizophoraceæ; the apetalous forms approximate in some degree to the Santalaceæ and Lauraceæ.

**Distribution.**—An Order comprising upwards of 200 species, generally distributed throughout the tropics.

**Qualities and Uses.**—The general property is astringency. The barks of *Bucida Buceras* and *Conocarpus racemosa* and of various *Terminaliæ* are used for tanning. The fruit of *Terminalia belerica*, the Myrobalan, is astringent and tonic. A kind of gum is obtained from the bark of *T. belerica* and *Combretum alternifolium*. *T. Benzoin* has a milky juice, which hardens into a fragrant gum-resin, used as incense in the Mauritius. The seeds of *T. Catappa* are eaten like almonds. Many of the plants are valuable timber-trees; and a number are cultivated on account of their showy flowers.

(ALANGIACEÆ are a small Order of exotic plants, timber-trees, or shrubs allied to Combretaceæ, but having albuminous seeds with large leafy cotyledons, and there are differences in the corolla and stamens. Lindley considers the plants related in some degree to Myrtaceæ, Melastomaceæ, and Onagraceæ, but, with Endlicher, thinks that, after Combretaceæ, their nearest relatives are probably Cornaceæ and Hamamelaceæ; Bentham and Hooker group them with Cornaceæ. The succulent fruits are edible, but the plants on the whole are of little importance. Genera: *Alangium*, L.; *Marlea*, Roxb.: *Nyssa*, Gronov., &c.)

## ORDER LXI. MELASTOMACEÆ.

*Class.* Myrtifloræ, *Endl.* *All.* Myrtales, *Lindl.* *Coh.* Myrtales, *Benth. et Hook.*

418. *Diagnosis.*—Myrtle-like plants, with opposite curved-ribbed leaves, showy flowers, definite stamens with remarkable appendaged anthers, bursting by pores at the apex. Seeds very numerous, minute, exalbuminous.

ILLUSTRATIVE GENERA.

Centradenia, *Don.*
Melastoma, *L.*
Osbeckia, *L.*
Rhexia, *Nutt.*
Medinilla, *Gaudich.*
Sonerila, *Roxb.*
Miconia, *DC.*
Memecylon, *L.*
Mouriria, *Juss.*

**Affinities.**—A large proportion of these plants are distinguishable at first sight by the several large curved ribs running from the base to the apex of the leaves; but this character does not hold in *Memecylon* or in *Mouriria*. In *Memecyleæ*, also, the usually flat cotyledons are convoluted, as in Combretaceæ and exceptional Myrtaceæ; *Mouriria* has the ribs of the leaves inconspicuous. The most striking character of the flower lies in the stamens with their oddly beaked anthers. But the Order differs from the Myrtaceæ also in the contorted æstivation of the corolla. On the other hand, they are allied to the *Lagerstrœmieæ* among the Lythraceæ, from which, however, the imbricate or twisted æstivation of the calyx and the characters above noted sufficiently distinguish them.

**Distribution.**—A large Order, the species of which are generally diffused within the tropics—a few also in North America, China, Australia, and N. India.

**Qualities and Uses.**—The members of this large Order seem to be all harmless; and the prevailing character is slight astringency. Many yield edible succulent fruits; the name of *Melastoma* is derived from the fruit staining the mouth black. The most striking peculiarities about the Order are, perhaps, the beauty of the flowers, and the curious ribbed appearance of the foliage. A large number of species are cultivated in this country, some as ornamental-foliage plants, others for the sake of their flowers.

## ORDER LXII. ONAGRACEÆ. THE EVENING-PRIMROSE ORDER.

*Class.* Calyciflorae, *Endl.* *All.* Myrtales, *Lindl.* *Coh.* Myrtales, *Benth. et Hook.*

419. *Diagnosis.*—Herbs or shrubs, with 4-merous (sometimes 2–3-merous) flowers; the tube of the calyx (of the receptacle) adhering to the 2–4-celled ovary, calyx-teeth valvate in the bud, or obsolete; the epigynous petals convolute; stamens as many, or twice as many, as the petals, and inserted with them; ovary 2–4-celled; styles united; stigma capitate or 4-lobed; fruit capsular or succulent, with 2–4 cells; seeds numerous, without albumen.

ILLUSTRATIVE GENERA.

Œnothera, *L.*
Godetia, *Spach.*
Clarkia, *Pursh.*
Epilobium, *L.*
Skinnera, *Forst.*
Fuchsia, *Plum.*
Lopezia, *Cav.*
Circæa, *Tournef.*
Trapa, *L.*

**Affinities.**—Onagrads are allied to Halorageæ, but differ in their often coloured calyx, absence of albumen, and simple style, from *Trapa* in their convolute imbricate corolla, from Combretaceæ by their plurilocular ovary. The parts of the flower in this Order are sometimes 2-merous—*Circæa*, while in *Lopezia* only one stamen exists. Sometimes the petals are absent; and occasionally the flowers are unisexual. *Trapa* is a genus of water-plants sometimes placed with Haloragaceæ, from which, however, its single style and exalbuminous embryo separate it. The floating leaves are flat, wedge-shaped, and entire, while the submerged ones are cut up into numerous very fine segments. The germination of *Trapa* resembles that of some endogenous plants.

**Distribution.**—The Order consists of a considerable number of species, natives chiefly of the temperate parts of Europe, North America, and India.

**Qualities and Uses.**—Harmless, sometimes slightly astringent. The berries of some Fuchsias are edible. They are best known by the numerous garden plants belonging to the Order, most of which are very showy. *Epilobium* has many native species, which are mostly weeds. *E. angustifolium*, however, and *E. hirsutum* are tall and handsome plants. Some of the *Œnotheræ* are called Evening-Primroses, from the yellow flowers opening in the evening. *Trapa* produces a large horned fruit with amygdaloid seeds with unequal cotyledons. *T. natans* is the Water-chestnut of the French. The seeds of *T. bispinosa*, the Singhara-nut (Kashmir), and *T. bicornis* (China) furnish important articles of food.

## ORDER LXIII. HALORAGACEÆ.

*Class.* Calycifloræ, *Endl.* *All.* Myrtales, *Lindl.* *Coh.* Rosales, *Benth. et Hook.*

420. *Diagnosis.*—Aquatic plants, with small axillary 2–4-merous flowers, often imperfect; calyx adherent, its teeth obsolete; petals often wanting; stamens 1–8; fruit indehiscent, 1–4-celled, with a solitary suspended seed in each cell; albumen fleshy.

### ILLUSTRATIVE GENERA.

Hippuris, *L.* | Myriophyllum, *Vaill.* | Haloragis, *Forst.*

**Affinities, &c.**—The Haloragaceæ are distinguished from Onagraceæ by the reduced calyx and the solitary pendulous and albuminous seeds; the corolla is absent from *Hippuris* and *Proserpinaca*. The former genus has a very simple flower, consisting merely of an adherent calyx with a very short limb, an ovary of one carpel, and a single stamen. The whorled foliage of *Hippuris* and the *Myriophylla* is very curious, giving the first somewhat the appearance of an *Equisetum*, while the latter are almost like some of the branched freshwater Algæ. Most of the Order are aquatic; but *Haloragis* and *Loudonia* are terrestrial and more or less shrubby. They are universally diffused, but generally of little importance.

## ORDER LXIV. LYTHRACEÆ.

*Class.* Calyciflorœ, *Endl.* *All.* Saxifragales, *Lindl.* *Coh.* Myrtales, *Benth. et Hook.*

421. *Diagnosis.*—Herbs, shrubs, or trees, with mostly opposite entire leaves; no stipules; the calyx enclosing, but free from, the 1–4-celled, many-seeded ovary and membranous pod, and bearing the 4–7 deciduous corrugated petals and 4–14 stamens in its throat, calyx-lobes valvate, the stamens lower down; style 1; stigma capitate, or rarely 2-lobed; capsule enclosed in the calyx, dehiscent; seeds numerous, exalbuminous.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Peplis, *L.* | Lythrum, *L.* | Lawsonia, *L.* |
| Ammannia, *Houst.* | Cuphea, *Jacq.* | Lagerstrœmia, *L.* |

**Affinities.**—In habit, as also in the striated calyx, these plants have some slight resemblance to Labiatæ; but their nearest relations are, on one side, with several Calycifloral Orders (from which, as Onagraceæ and Melastomaceæ, they differ most strikingly in the superior position of the ovary), and on the other with Saxifragaceæ. From Rhizophoreæ they differ in their want of stipules and in their numerous ovules. From Myrtles, besides the above characters, they may be distinguished by their valvate calyx.

**Distribution.**—A considerable Order, the members of which are generally diffused, the tribe *Lagerstrœmieæ* tropical. *Lythrum Salicaria*, a common British plant, is remarkable for being found as the only representative of the Order in Australia. Its flowers are, according to Darwin, trimorphic, the stamens and styles being of three different lengths; two of these forms coexist in the same flower, and have different sexual functions.

**Qualities and Uses.**—Many of the plants have astringent properties; several are valuable as dyes. *Lawsonia inermis* is the celebrated Hennah or Henné of the East, used by women to dye their finger-nails, hands, or feet of a brown-orange colour; it is also used for dyeing Morocco-leather. The flowers of *Grislea tomentosa* are also used for dyeing in India. *Ammannia vesicatoria* is acrid, and has blistering properties. *Physocalymma floribunda*, a Brazilian tree, has a beautiful rose-coloured wood. *Cuphea* contains many favourite cultivated species. Bentham and Hooker place *Punica* (the Pomegranate) in this Order; but it would seem to belong more nearly to the Myrtles.

## ORDER LXV. SAXIFRAGACEÆ. SAXIFRAGES.

*Class.* Corniculatæ, *Endl.* *All.* Saxifragales and *All.* Grossales, *Lindl.* *Coh.* Rosales, *Benth. et Hook.*

422. *Diagnosis.*—Herbs, shrubs, or trees, with the pistils mostly

fewer than the petals or divisions of the calyx (usually 2, coherent below, and separate or separating above); the petals sometimes wanting), with the (mostly 4–10) stamens, inserted on the calyx, which is either free or more or less adherent to the 1–4-celled ovary (fig. 370).

Fig. 370.

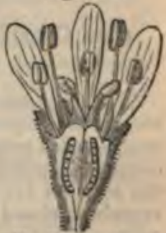


Fig. 370. Section of the flower of *Saxifraga*.

*Character.*

*Calyx* 5-parted, more rarely 3-, 4-, or 10-parted, more or less adherent to the ovary.

*Corolla*: *petals* imbricate, perigynous, equal in number to the segments of the calyx, and alternate with them, rarely absent.

*Stamens* inserted with the petals, equal in number to them and alternate, twice as many, or indefinite.

*Ovary* mostly of 2 carpels, more rarely of 3 or 4 or 5, more or less united into a 2- or more-celled ovary, usually half or wholly inferior; placentas axile; *styles* as many as the cells of the ovary; more or less coherent.

*Fruit* usually capsular, dehiscent: *seeds* mostly numerous, small, with fleshy albumen.

This extensive group of plants is divisible into four Suborders, which are by some authors regarded as distinct Orders:—

1. SAXIFRAGEÆ. Herbs: stipules absent or adnate; petals imbricated, or rarely convolute in the bud; calyx free, or partly adherent. ovary 1–3-celled.

2. ESCALLONIEÆ. Shrubs with alternate simple glandular leaves and no stipules: calyx imbricated in the bud.

3. PHILADELPHEÆ. Shrubs with opposite simple leaves and no stipules; calyx valvate; stamens epigynous.

4. CUNONIEÆ. Trees or shrubs with opposite or whorled, simple or compound leaves, and large interpetiolar stipules; petals never valvate.

ILLUSTRATIVE GENERA.

Suborder 1. SAXIFRAGEÆ.
  Saxifraga, *L.*

Suborder 2. ESCALLONIEÆ.
  Escallonia, *Mutis.*

Suborder 3. PHILADELPHEÆ.
  Philadelphus, *L.*
  Deutzia, *Thunb.*
  Hydrangea, *L.*

Suborder 4. CUNONIEÆ.
  Cunonia, *L.*

**Affinities.**—The relations of this Order are somewhat complicated, in consequence of the variety of conditions existing among the genera. The herbaceous *Saxifrageæ* are related to the Crassulaceæ in several respects, but differ in habit and in the absence of hypogynous glands—and also to the Rosaceæ, through *Spiræa*, *Astilbe*, &c.; from these, *Deutzia* leads to the shrubby forms, where *Philadelphus* manifestly approaches the Myrtaceæ, while the inflorescence of *Hydrangea* is like that of some Caprifoliaceæ. The *Cunonieæ* are scarcely distinguished, except by habit, from the *Saxifrageæ*; the *Escallonieæ*, passing off from the *Philadelpheæ*, are related to Ribesiaceæ, and more distantly to those Ericaceæ with an inferior ovary. Bruniaceæ differ in their dicoccous fruit; Saxifragaceæ are closely allied to Lythraceæ, but in the latter the embryo is exalbuminous. *Parnassia* is referred here by Hooker, but seems more closely to resemble Hypericaceæ. The Australian Pitcher-plant (*Cephalotus follicularis*), the leaves of which are tubular, with a lid closing the tube, belongs to a genus closely allied to Saxifrages, especially to the apetalous ones. From Rosaceæ it differs in the presence of albumen in the seed.

**Distribution.**—A large group; the *Saxifrageæ* are northern and alpine plants; the *Escallonieæ* are chiefly mountain plants of South America; the *Philadelpheæ* belong to South Europe and the temperate regions of Asia and America; the *Cunonieæ* occur in the East Indies, the Cape, Australia, and South America.

**Qualities and Uses.**—No important properties are attributed to this Order; a certain degree of astringency prevails in *Saxifrageæ* and *Cunonieæ*. Their chief merit consists in the beauty of the many cultivated species of alpine herbs, and of the hardy and half-hardy flowering shrubs. The Saxifrages, *Deutzia*, *Heuchera*, and *Escallonia*, *Hydrangea*, and others are familiar to every one. *Philadelphus coronarius*, the "Syringa" or Mock-Orange of our shrubberies, a native of the south of Europe, is remarkable both for the beautiful flowers (the sweet perfume of which depends on the presence of an essential oil) and the peculiar flavour of the foliage, resembling that of the cucumber.

(The genus *Henslovia*, Wall., once considered to be allied to Saxifragaceæ, turns out to be identical with *Crypteronia*, Blume, which is included in Lythraceæ by Bentham and Hooker. The genus consists of three or four trees of tropical India, related apparently to *Philadelpheæ*, by *Hydrangea*, and more closely with Brexiaceæ, but that they have opposite leaves. In habit they resemble *Caprifolium*.)

(FRANCOACEÆ is an Order composed of Chilian herbs with the habit of Saxifrages, and flowers 4-merous throughout calyx, corolla, stamens (in several circles), and carpels. Some authors consider them nearest to Saxifragaceæ, others to Crassulaceæ, others to Rosaceæ; Lindley believes their nearest affinity is to Droseraceæ. Genera: *Francoa*, Cav.; *Tetilla*, DC.)

## ORDER LXVI. CRASSULACEÆ. THE STONE-CROP ORDER.

*Class.* Corniculatæ, *Endl.* *All.* Violales, *Lindl.* *Coh.* Rosales, *Benth. et Hook.*

423. *Diagnosis.*—Succulent herbs or low shrubs with perfectly symmetrical flowers, the petals and pistils equalling the sepals in number (3–20), and the stamens as many or twice as many; albumen fleshy.

### *Character.*

*Calyx* free, mostly 5-parted, rarely 3–10-parted, imbricated in the bud, persistent.

*Corolla*: *petals* as many as the lobes of the calyx and alternate with them, distinct or united below, emerging from the bottom of the calyx, imbricated in æstivation.

*Stamens* as many as the petals and alternate with them, or twice as many (in 2 circles), free or adherent to the (coherent) petals.

*Ovaries*: *carpels* in a circle, as many as the petals and opposite to them, often with a glandular scale at the base outside, distinct or more or less coherent; placentas at the ventral suture; *styles* distinct; *stigmas* on the inside.

*Fruit*: a circle of dry follicles, or a capsule bursting at the dorsal sutures or by the separation of the walls as valves from the septa; *seeds* varying in number, very small; embryo in the axis of fleshy albumen.

### ILLUSTRATIVE GENERA.

Suborder 1. CRASSULEÆ. *Fruits follicular.*

Tillæa, *Mich.*
Crassula, *Haw.*
Bryophyllum, *Salisb.*
Cotyledon, *DC.*
Sedum, *L.*
Sempervivum, *L.*

Suborder 2. DIAMORPHEÆ. *Carpels coherent into a plurilocular capsule.*

Diamorpha, *Nutt.*
Penthorum, *L.*

**Affinities.**—This very peculiar Order appears to be nearly related to the Saxifragaceæ, especially by the genera with capsular fruit; and on the other hand to Paronychiaceæ and hence to Caryophyllaceæ. They are most remarkable for their succulent foliage, possessed of a power of subsisting almost entirely on atmospheric elements, and resisting most obstinately the influence of heat and drought. They are exceedingly tenacious of life; and *Bryophyllum* in particular is celebrated for the aptitude of its leaves to produce adventitious buds (§ 109) when separated and placed in favourable circumstances. The symmetrical construction of the flowers is likewise very interesting to the botanist, and has been dwelt on in the Morphological Part of this work (§ 147). The Houseleek, *Sempervivum tectorum*, occasionally produces monstrous stamens, with ovules in place of pollen.

**Distribution.**—There are a considerable number of species, generally found in the extratropical regions, in very dry situations, and especially abundant at the Cape of Good Hope.

**Qualities and Uses.**—Their properties are mostly unimportant. *Sedum acre*, the common yellow Biting Stone-crop of our walls, is so called from its acridity, and is said to be emetic and purgative. Some are eaten; others used as refrigerants. *Cotyledon Umbilicus* has been used in epilepsy.

## ORDER LXVII. PARONYCHIACEÆ OR ILLECEBRACEÆ.

*Class.* Caryophyllinæ, *Endl.* *All.* Silenales, *Lindl.* *Coh.* Chenopodiales.

424. *Diagnosis.*—Herbs or shrubs with mostly opposite leaves and often scarious stipules, minute flowers, with 5- or more, rarely 3- or 4-merous calyx; petals small or absent; stamens on the calyx, 1–10; ovary 1-, rarely 3-celled; ovules numerous on a free central placenta, or solitary on a long funiculus from the base of the ovary. Seeds albuminous; embryo curved.

ILLUSTRATIVE GENERA.

Subord. 1. PARONYCHIEÆ. *With scarious stipules; stamens opposite the sepals.*

Corrigiola, *L.*
Paronychia, *Juss.*
Illecebrum, *Gærtn. f.*
Polycarpon, *Lœfl.*
Spergularia, *Pers.*
Spergula, *L.*

Subord. 2. SCLERANTHEÆ. *Without stipules; calyx with an indurated tube; petals none; stamens opposite the sepals.*

Scleranthus, *L.*

Suborder 3. MOLLUGINEÆ. *Stamens alternate with the sepals when equal; if fewer, alternate with the carpels.*

Mollugo, *L.*

**Affinities, &c.**—This Order consists of upwards of a hundred species, and may be regarded as a degeneration of Caryophyllaceæ, from which they differ in the possession of stipules, the thin petals &c. forming a transition to the apetalous Chenopodiaceæ and Amaranthaceæ. They are also nearly related to Portulacaceæ, differing from some of the genera of that Order only by the position of the stamens opposite the sepals. Some of them are succulent, like the Crassulaceæ, but are distinguished by the structure of the ovary. They are mostly valueless weeds, abounding in barren sandy tracts throughout the temperate regions of the globe.

## ORDER LXVIII. PORTULACACEÆ.

*Class.* Caryophyllinæ, *Endl.* *All.* Silenales, *Lindl.* *Coh.* Caryophyllinæ, *Benth. et Hook.*

425. *Diagnosis.*—Herbs with succulent leaves and regular unsymmetrical flowers (sepals fewer than the petals); sepals 2, rarely 3 or 5; petals mostly 5 or 0; stamens opposite the petals when of the same number, but often indefinite. Capsule 1–5-celled, with few or many seeds on long funiculi from the base, or on a free central placenta; embryo curved; round floury albumen.

ILLUSTRATIVE GENERA.

Tetragonia, *L.*
Aizoon, *L.*
Sesuvium, *L.*

Portulaca, *Tournef.*
Talinum, *Adans.*

Claytonia, *L.*
Montia, *Michel.*

**Affinities, &c.**—This Order, as here regarded, has various relations, and is not well defined. It approaches very closely to Caryophyllaceæ through Paronychiaceæ, but may be distinguished by the 2-parted calyx and the number and position of the stamens. Like Paronychiaceæ, the members of this Order are nearly related to the proper apetalous Orders, Chenopodiaceæ &c. Lindley separates the *Tetragonieæ*, *Aizoideæ*, and *Sesuvieæ* in an Order called Tetragoniaceæ, differing from Portulacaceæ in their apetalous flowers, multilocular ovary, and distinctly perigynous stamens. Portulacaceæ would thus be defined chiefly by a 2-sepalous calyx, hypogynous or rarely perigynous stamens, and 1-celled ovary. Bentham and Hooker refer the Tetragonieæ to Mesembryanthaceæ, from which they differ in their apetalous flowers. *Portulaca* is exceptional in its partially inferior ovary and perigynous stamens; hence the Order, as a whole, is considered by Bentham and Hooker to belong rather to the Thalamifloræ than to the Calycifloræ. The plants of this Order are generally diffused, in waste, dry places. *Portulaca oleracea*, Purslane, is an old-fashioned pot-herb; others are used in the same way. *Tetragonia expansa* furnishes New-Zealand Spinach. *Claytonia tuberosa* has an edible tuber. Many have showy but ephemeral flowers. *Lewisia redivivа* (Oregon) has a starchy root, used as food under the names of spatulum or spætlum and *racine amère*; it is pungent and aromatic when raw.

## ORDER LXIX. MESEMBRYANTHACEÆ OR FICOIDEÆ.
### ICE-PLANTS.

*Class.* Caryophyllinæ. *All.* Ficoidales, *Lindl.* *Coh.* Ficoidales, *Benth. et Hook.*

426. *Diagnosis.*—Shrubby or succulent herbaceous plants, with opposite simple leaves; sepals definite; petals very numerous; stamens indefinite, perigynous; ovary inferior or almost superior, many-celled or 1-celled; ovules numerous, attached by cords to a free central placenta or to axile placentas, or to parietal placentas spreading over the back of each cell; seeds numerous; embryo curved or spiral, on the outside of mealy albumen.

ILLUSTRATIVE GENUS.

Mesembryanthemum, *L.*

**Affinities.**—Very nearly related to Portulacaceæ and Paronychiaceæ. From the former they differ in the parietal, not free central placenta, from the latter in the position of the stamens, many-celled ovary, and dehiscence of the capsule. The structure of the ovary is curious, presenting very different conditions in different members of the Order; probably it is somewhat analogous to that of Cucurbitaceæ, and the diverse positions of the placentas depend on the degree of involution of the carpels and the disruption of the septa. The parietal placenta, together with the presence of numerous petals, serve to indicate a relationship to Cactaceæ. Bentham and Hooker refer to this Order *Tetragonieæ* (see Portulacaceæ) and *Mollugineæ* (see Paronychiaceæ). The plants are remarkable for their succulent foliage, accompanied sometimes by water-vesicles or pseudo-glands on the epidermis, whence the name of Ice-plant applied to *Mesembryanthemum crystallinum.* The ripe capsules are very hygrometric, the valves opening when wet and closing when dry.

**Distribution.**—A rather large Order, of which the majority belong to the sandy tracts of the Cape, but a few are found in S. Europe, America, China, and the South Seas.

**Qualities and Uses.**—The foliage of *M. edule* (Hottentots' fig) is eaten at the Cape; *M. emarcidum* acquires narcotic properties when fermented. Several are burnt for the soda-ash in Egypt, Spain, &c. The seeds of some yield a kind of flour.

## ORDER LXX. PAPAYACEÆ. THE PAPAW ORDER.

*Class.* Parietales, *Endl.* *All.* Papayales, *Lindl.* *Coh.* Passiflorales, *Benth. et Hook.*

427. *Diagnosis.*—Trees or shrubs, sometimes with an acrid milky juice, alternate, lobed, long-stalked leaves, and diclinous, sometimes hermaphrodite, dichlamydeous flowers. Male fl.:—calyx free, minute, with 5 teeth; corolla monopetalous, with 5 lobes; stamens definite, epipetalous. Female fl.:—Petals 5; corona filamentous or fimbriate, sometimes none; ovary free, 1-celled, with 3–5 many-seeded parietal placentas; fruit succulent or dehiscent; embryo in the axis of fleshy albumen.

### ILLUSTRATIVE GENERA.

Carica, *L.* | Modecca, *L.* | Ceratosicyos, *Nees.*

**Affinities, &c.**—The present Order stands near to Cucurbitaceæ and to Passifloraceæ, differing, however, in important respects from both,—since the former have an inferior ovary and exalbuminous seeds; the latter, hermaphrodite flowers and a characteristic coronet arising from the tube of the flower, of a different nature to the staminodes or sterile stamens of the present group. Bentham and Hooker include it under Passifloraceæ. The Papaw-tree, *Carica Papaya*, has a succulent fruit, edible when cooked, but the juice of the unripe fruit and the seeds appear to be very acrid. *C. digitata* (Brazil) is regarded as a very deadly poison, and its juice blisters the skin. The species of *Carica* are natives of South America, the other genera are East-Indian or African.

(PANGIACEÆ are an Order of arborescent plants closely related to Papayaceæ, differing chiefly in being polypetalous, and by the female flowers having scales in the throat; the number of parts in the floral circles also appears more variable. They constitute a Tribe of Bixaceæ in the 'Genera Plantarum' of Bentham and Hooker. They are poisonous plants found in the hotter parts of India. *Hydnocarpus venenatus* is a native of Ceylon; its fruit produces dangerous intoxication. The seeds of *Pangium* are sometimes used, after boiling and extraction with water, as a spice, but even then have cathartic properties. Genera: *Pangium*, Reinw.; *Gymnocarpea*, R. Br.; *Hydnocarpus*, Gærtn.)

## ORDER LXXI. PASSIFLORACEÆ. PASSION-FLOWERS.

*Class.* Parietales, *Endl.* *All.* Violales, *Lindl.* *Coh.* Passiflorales, *Benth. et Hook.*

428. *Diagnosis.*—Climbing plants, rarely erect trees, with tendrils and foliaceous stipules; leaves and leaf-stalks often glandular; flowers perfect; calyx 5-parted, with numerous filamentous processes springing from the tube of the flower (receptacle), inside the 5 petals; stamens 5, monadelphous, adherent to the stalk of the 1-celled ovary, which latter is free from the calyx, and has 3 or 4 parietal placentas and as many clavate styles; fruit mostly succulent, stalked; seeds numerous, arillate; embryo straight, in thin fleshy albumen.

### ILLUSTRATIVE GENERA.

Smeathmannia, *Soland.* | Passiflora, *Juss.* | Tetrapathæa, *DC.*

**Affinities.**—This Order, which resembles the Cucurbitaceæ in habit, has a further affinity in the structure of the ovary, the most marked difference being the superior position of that organ and the presence of albumen in Passion-flowers. The coronet or wreath of filiform organs between the petals and the stamens, and the gynandrophore bearing the stamens and ovary, mark this Order out very clearly, and ordinarily its flowers are perfect; but the genus *Tetrapathæa* appears to connect it by a further link with Cucurbitaceæ, since the flowers are there polygamous or even diœcious. It is closely allied to Samydaceæ, in which, however, there is no corona. From Turnerads it differs in the gynandrophore, and marcescent not deciduous petals. The relations to Capparidaceæ, Bixaceæ, and Violaceæ are more remote.

**Distribution.**—A considerable Order in point of numbers: the greater part are South-American and West-Indian; a few occur in North America, Africa, and the East Indies.

**Qualities and Uses.**—The pulpy fruits of many species of *Passiflora* (Granadillas), several *Tacsoniæ*, and of *Paropsia edulis* are eaten; but astringent properties exist in the leaves, while the roots of *Passiflora quadrangularis* and the flowers of *P. rubra* are narcotics. The beauty of the flowers and foliage renders this Order a very favourite one in cultivation. *Passiflora cærulea* is hardy, but most of the other species and the *Tacsoniæ* are greenhouse or stove climbers.

(MALESHERBIACEÆ consists of a few unimportant herbs or low shrubs, natives of Chili and Peru, resembling Passifloraceæ in the structure of the flowers; but the coronet is merely a membranous ring, the styles arise from the backs of the carpels, and the seeds are not arillate. Included as a Tribe of the preceding Order by Bentham and Hooker.)

(TURNERACEÆ. Herbs or half shrubby plants, natives of the West Indies and South America, with 5-merous flowers, deciduous contorted petals with no corona, and a 1-celled superior ovary with 3 parietal placentas; seeds albuminous, with a strophiole or false aril. They appear to form a link, through Malesherbiaceæ, from the Passifloraceæ &c. to parietal Thalamifloral Orders, such as Cistaceæ. They have tonic and aromatic properties. Genera: *Turnera*, Plum.; *Piriqueta*, Aubl.)

(Samydaceæ form a tropical Order, chiefly of American plants, of somewhat doubtful place: apparently they stand nearest to Bixaceæ and the Thalamifloræ with parietal placentas; however, they are apetalous, and the stamens are perigynous, which relate them to a different set of Orders. One of their most striking peculiarities is the presence of both round and linear pellucid glands in the leaves. The bark and leaves of the plants are astringent, and those of species of *Casearia* are used in Brazil as febrifuge medicines.)

## Order LXXII. CUCURBITACEÆ. The Cucumber Order.

*Class.* Peponiferæ, *Endl.* *All.* Cucurbitales, *Lindl.* *Coh.* Passiflorales, *Benth. et Hook.*

429. *Diagnosis.*—Herbaceous plants, mostly succulent, prostrate or climbing, with tendrils; leaves alternate; flowers diœcious or monœcious; the flower-tube adherent to the 1–3-celled ovary; corolla none; and the 3–5 stamens commonly more or less united by their often sinuous anthers as well as by their filaments. Fruit a pepo, or, more rarely, a succulent berry. Placentas confluent in the axis; albumen none.

### *Character.*

*Calyx* adherent in the female flowers, 5-toothed, sometimes without a limb.

*Corolla* of distinct valvate petals, or 4–5-parted, sometimes fringed;

Fig. 371.

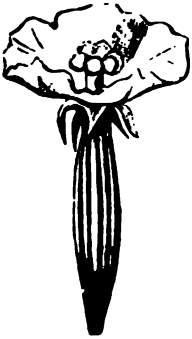


Fig. 372.

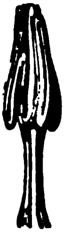


Fig. 373.

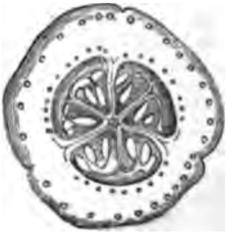


Fig. 371. Female flower of *Cucurbita*.
Fig. 372. Staminal column of male flower of Gourd.
Fig. 373. Section of the fruit of the Cucumber.

springing from the calyx, and with the lobes alternating with those of the calyx.

♂. *Stamens* 5, springing from the corolla and alternate with its segments, more rarely 3 or 2, sometimes free, monadelphous, or more frequently triadelphous, with 2 pairs and 1 odd one; *anthers* 2-celled, usually long and sinuous, or bent upon themselves laterally (fig. 372), sometimes straight, free, or combined.

♀. *Ovary* inferior (fig. 371), 3-celled; usually with 3 placentas placed parietally, but on the involute margins of the carpels so as to meet in the centre (fig. 373), sometimes with 2 placentas and 2 erect ovules, or 1-celled with a solitary pendulous ovule; *style* short; *stigmas* thickened, papillose, lobed or fringed.

*Fruit* more or less succulent; a pepo with a firm rind, or a juicy berry with a thin skin; *seeds* mostly flattened, with a succulent or membranous coat over the leathery or horny testa, which presents a marginal ring or keel; *embryo* flat, without albumen.

### ILLUSTRATIVE GENERA.

Series 1. PLAGIOSPERMEÆ. *Ovules horizontal.*

Telfairia, *Hook.*
Feuillæa, *L.*
Anguria, *L.*
Bryonia, *L.*
Mukia, *Arn.*
Citrullus, *Neck.*
Ecbalium, *L. C. Rich.*
Momordica, *L.*
Luffa, *Tournef.*
Lagenaria, *Ser.*
Cucumis, *L.*
Cucurbita, *L.*

Series 2. ABOBREÆ. *Ovules erect or ascending.*

Trianosperma.
Elaterium.

Series 3. CREMOSPERMEÆ. *Seed solitary, pendulous.*

Sicyos, *L.*
Sechium, *P. Br.*

**Affinities, &c.**—The Cucurbitaceæ, divided as above into 3 series, are still further divided into tribes according to the number of the stamens, the form of the anthers, the nature of the placentas, and the number of the ovules &c. They form a very well-defined Order, but have affinities of a very diversified range. The habit and the placentation ally them closely with Passifloraceæ, from which they differ, however, in the position of the ovary, the unisexual flowers, the peculiar structure of the anthers, and the want of albumen. Their nearest relations among the epigynous Orders, after Begoniaceæ, appear to be the Loasaceæ, through *Gronovia*, which agrees in its climbing habit, and comes near the *Sicyeæ*. In the structure of the ovary and seeds and the position of the stamens there is a certain approach to the polypetalous Onagraceæ, Myrtaceæ, &c., and, further, to the monopetalous Campanulaceæ. Again, the diclinous condition and the structure of the ovary connect them with Papayaceæ. This Order presents a number of points of interest as regards structure. The tendrils appear here to be partially metamorphosed leaves, while their base is constituted of an abortive branch; the construction of the ovary of the *Cucurbiteæ* is remarkable, the sides of the carpels being inflected to the centre, and then rolled in further upon themselves until the marginal placentas are brought back nearly to the circumference of the fruit; hence, although termed parietal placentas, they are rather an excessive case of the inflexion which ordinarily produces axile placentas. The form of the fruit is varied: the pepo assumes almost every modification of globular, oval, bottle-shape, sausage-like, or even snake-like form: some kinds are dehiscent; in *Ecbalium* it bursts by separating from its peduncle and expelling the seeds with violence through the orifice; in *Momordica* and others it bursts irregularly; in *Elaterium* it bursts by two or three valves at the summit; and in some species of *Luffa* an orifice is formed at the top by the separation of the scar of the calyx. In *Sechium* the pepo contains only one seed, which germinates within the fruit, and never separates from it, so that the fruit resembles a thick root-stock.

**Distribution.**—A considerable Order, the species of which are chiefly natives of hot climates, especially abounding in the East Indies, but some found almost everywhere; *Bryonia dioica* is the only British species.

**Qualities and Uses.**—The majority of the plants of this Order are to be looked upon as suspicious, from the prevalence of a purgative property, sometimes very violent, sometimes slight, and apparently liable to affect particular constitutions more strongly than others. Some kinds may be reckoned as poisons, while others, especially when cultivated, although they retain laxative qualities, become innocuous.

Among the decided purgatives, *Ecbalium agreste*, the dried juice of the fruit of which furnishes "Elaterium," is one of the most drastic agents known. Colocynth is the extract of the pulp of *Citrullus Colocynthis*; the fruits of several species of *Luffa* and *Lagenaria* are strongly purgative; the roots of the various species of *Bryonia* are actively cathartic; and the same quality resides in the seeds of *Feuillæa cordifolia* &c. Some other plants of the Order share this quality, although the seeds are generally harmless.

On the other hand, the milder species furnish fruits highly esteemed either as fruits, for their delicate flavour in their fresh state, as in the Melon and the Cucumber, or as pot-herbs, from the succulent, bland, pulpy substance of the unripe or ripe fruit, as of the Gourds. *Cucumis Melo* is the common Melon; *Cucumis sativus* is the Cucumber; *Cucurbita Citrullus* is the Water-melon; *Cucurbita Pepo* is the White Gourd, *C. maxima* the Red Gourd or Pumpkin; the Vegetable-marrow is a variety of *C. Pepo*. The Snake-gourd, *Trichosanthes anguina*, is eaten in India, also many other species of Cucurbitaceous plants, which appear to become much milder under cultivation. The fruit of *Sechium edule* is also eaten in hot countries. The seeds are oily; some are harmless, as those of *Telfairia pedata* (Africa), which are said to be as large as chestnuts, and are eaten like almonds, and the oil expressed. The pulp surrounding them is very bitter.

## ORDER LXXIII. BEGONIACEÆ. ELEPHANT'S EARS.

*Class.* Peponiferæ, *Endl.* *All.* Cucurbitales, *Lindl.* *Coh.* Passiflorales, *Benth. et Hook.*

430. *Diagnosis.*—Herbaceous plants or low succulent shrubs with an acid juice; leaves alternate, oblique at the base, with large scarious stipules;

flowers diclinous; sepals coloured, those of the barren flowers in two pairs, decussating; those of the fertile flowers 5, imbricated, or 8; stamens indefinite, distinct or coherent in a column; anthers clustered; ovary inferior, 3-celled, with 3 dissepimental placentas meeting in the axis; stigmas 3, sessile, 2-lobed; seeds exalbuminous, with a thin reticulated testa.

### ILLUSTRATIVE GENERA.

Begonia, *L.* | Hillebrandia, *Oliv.*

**Affinities, &c.**—The relations of this interesting and numerous Order have been variously conceived by different authors; but they appear to be very near Cucurbitaceæ, the so-called parietal placentas of the latter being rather an excessive form of the double axile placentas of such plants as *Diploclinium*, and the placentas of *Mezieria* are described as parietal. *Hillebrandia* has nearly regular flowers, and the ovary opens at the top as in *Reseda*. It confirms the relationship to Datiscads. They are natives chiefly of India, South America, and the West Indies, and are much cultivated for their beauty; the oblique or unequal-sided leaves are characteristic, whence they are sometimes called Elephant's Ears. Many *Begonias* are remarkable for the production of adventitious buds in great numbers from various parts of their surface. The roots appear to be bitter and astringent, sometimes purgative. *B. malabarica, tuberosa,* and some others are used as pot-herbs.

(DATISCACEÆ are diclinous apetalous herbs or trees, with alternate, exstipulate, simple or compound leaves; barren flowers with a 3–4-merous perianth and 3–7 stamens; fertile ones with an adherent 3–4-toothed perianth, a 1-celled ovary with 3–4 many-seeded parietal placentas, and a dry fruit opening at the summit. They consist of a few species very widely scattered. *Datisca cannabina* is found in the south-east part of Europe, and has bitter and purgative properties. The Order appears so nearly related to Cucurbitaceæ, Begoniaceæ, and Loasaceæ, that it is undesirable to place it among the Monochlamydeæ. *D. cannabina* is remarkable as affording one of the examples of a tendency of the female flowers of diœcious plants to mature seeds without impregnation; this phenomenon has been observed frequently in *Cœlobogyne* and *Mercurialis* among the Euphorbiaceæ and in *Cannabis*; but some error of observation is to be suspected in these cases. *Tetrameles* is a large tree, the rest are herbs. Genera: *Datisca*, L.; *Tetrameles*, R. Br.; *Tricerastes*, Presl.)

(HOMALIACEÆ are a small Order of tropical trees or shrubs with inferior ovaries and parietal placentas, related on the one hand to Passifloraceæ, on the other to Loasaceæ and Cactaceæ. They are included in Samydaceæ by Bentham and Hooker; some of them have been introduced into cultivation on account of their foliage; the flowers are small. Genera: *Homalium*, Jacq.; *Blackwellia*, Commers., &c.)

## ORDER LXXIV. LOASACEÆ.

*Class.* Parietales, *Endl.* *All.* Cactales, *Lindl.* *Coh.* Passiflorales, *Benth. et Hook.*

431. *Diagnosis.*—Herbs; sometimes hispid with stinging hairs; leaves opposite or alternate, without stipules; calyx adherent, 4–5-parted; petals 5 or 10, in 2 circles, often cucullate; stamens numerous, free or in bundles adherent to the petals, often intermixed with staminodes or abortive stamens; ovary 1-celled, with several parietal placentas or 1 central; ovules pendulous; seed with a loose testa; embryo in the axis of fleshy albumen.

### ILLUSTRATIVE GENERA.

Mentzelia, *L.*
Bartonia, *Sims.*
Loasa, *Adans.*
Blumenbachia, *Schrad.*
Gronovia, *L.*

**Affinities, &c.**—A small Order. The Genus *Gronovia*, with a climbing habit, connects this Order with Cucurbitaceæ, especially those with a single seed; but in the latter Order the seeds are exalbuminous. It is likewise closely related to Cactaceæ, differing importantly in habit only from some genera. With Begoniads it agrees in the character of the seeds. A further affinity exists to the epigynous Order Onagraceæ; and among those with a free ovary, Malesherbiaceæ, Turneraceæ, and Passifloraceæ exhibit some points of agreement. They are natives chiefly of America; but some occur in other parts of the globe, in temperate and tropical climates. They are principally remarkable for their stinging hairs, which produce more violent irritation than our indigenous Nettles. *Mentzelia hispida* has a purgative root. *Loasa, Bartonia,* &c. are often cultivated on account of the beauty of their flowers; but some of them are rendered less valuable by their stinging-property.

## ORDER LXXV. CACTACEÆ. INDIAN FIGS.

*Class.* Opuntiæ, *Endl.* *All.* Cactales, *Lindl.* *Coh.* Ficoidales, *Benth. et Hook.*

432. *Diagnosis.*—Fleshy and thickened, mostly leafless plants, of peculiar aspect, globular or columnar and many-angled, or flattened and jointed, usually with prickles. Flowers solitary, sessile; the calyx and corolla sometimes 4-merous, but generally undistinguishable and imbricated in several circles adherent to the 1-celled ovary; stamens indefinite; placentas parietal; fruit succulent; seeds numerous, parietal or in the pulp, exalbuminous.

### ILLUSTRATIVE GENERA.

Mammillaria, *Haw.*
Echinocactus, *Link et Ott.*
Cereus, *Haw.*
Phyllocactus, *Link.*
Rhipsalis, *Gærtn.*
Opuntia, *Tournef.*
Pereskia, *Plum.*

**Affinities, &c.**—These plants are generally distinguishable at first sight by the remarkable forms of their succulent stems and the absence of true leaves; but this anomalous condition of the stem is not a decisive character, nor does it even carry with it indications of affinity, since we find it among Euphorbiaceæ, in *Stapeliæ* among the Asclepiadaceæ, in Vitaceæ, and elsewhere. The ordinary forms scarcely require description; but it must be noticed that the leaf-like structures of *Epiphyllum* &c. are branches, and the leaves are represented solely by spines in the common kinds, each tuft of spines representing an abortive shoot with undeveloped internodes; *Pereskia*, however, bears true leaves, sessile or stalked. The stems have a woody axis of the normal Dicotyledonous structure: the chief mass of the stem of the phylloid kinds is made up of the greatly developed cortical parenchyma; but the globular and columnar kinds are very solid: the wood is remarkable for a peculiarly formed spiral thickening of its cells; and the parenchyma of old stems is densely loaded with crystals of oxalate of lime.

The relations, as founded on the structure of the flowers, are, perhaps, closest with Loasaceæ, and beyond them with the Cucurbitaceæ, with, however, many important points of difference from the last. There is a considerable resemblance in certain respects to Mesembryanthaceæ; for the placentas of that Order and those of the present are apparently but slight modifications of a similar fundamental structure. Some degree of affinity exists between Cactaceæ and Ribesiaceæ; but the dicarpellary structure there and the albuminous seeds are important distinctions, and indicate a closer relationship of the latter plants to Saxifragaceæ.

**Distribution.**—A large Order, the members of which are almost exclusively found in the hotter parts of America, especially in dry situations. *Opuntia vulgaris* is naturalized in South Europe and elsewhere. A species of *Rhipsalis* occurs in Africa.

**Qualities and Uses.**—A subacid juice is commonly present in these plants, whence some of them are esteemed as remedies in fevers; the pulpy fruit of some is agreeable on account of this quality, in others it is insipid and mucilaginous. Cattle are said to bruise the trunks of some species with their hoofs in order to browse on the succulent parenchyma. *Opuntia vulgaris* is the Prickly Pear, the fruit of which is esteemed in the south of Europe and America. The fruit of *O. Tuna* yields a carmine pigment; that of *Pereskia aculeata* is called the Barbadoes Gooseberry. *O. coccinellifera*, the Nopal plant, is celebrated as forming the habitation and sustenance of *Coccus Cacti*, the Cochineal insect. *Cereus grandiflorus*, *C. nycticalus*, and some others are noted for opening their magnificent flowers at night: these and many other species of this and other genera of the Order, such as *Epiphyllum*, *Phyllocactus*, *Rhipsalis*, &c., are highly valued in cultivation for their showy flowers; and the globular, columnar, and angular stems are not less remarkable, on account of their strange appearance.

## ORDER LXXVI. RIBESIACEÆ OR GROSSULACEÆ.
## CURRANTS.

*Class.* Corniculatæ, *Endl.* *All.* Grossales, *Lindl.* *Coh.* Rosales, *Benth. et Hook.*

433. *Diagnosis.*—Low shrubs, sometimes prickly, with alternate palmately lobed leaves, a 5-lobed calyx adhering to the 1-celled ovary and bearing 5 stamens alternating with as many small petals. Fruit a 1-celled, inferior berry with 2 parietal placentas. Seeds numerous, imbedded in pulp; embryo minute, in abundant horny albumen.

### ILLUSTRATIVE GENUS.

Ribes, *L.*

**Affinities.**—These plants were formerly associated in the same Order with Cactaceæ; but their structure differs importantly, and approaches so nearly to that of Saxifragaceæ, that *Polyosma* is placed among the *Escalloniea* by some authors, and in this Order by others: the succulent fruit and the horny albumen are almost the only criteria, since the placentas are parietal in some *Escalloniea*. By Bentham and Hooker this Order is included under Saxifragaceæ as a distinct Tribe.

**Distribution.**—Cool or shady localities in the temperate regions of Europe, Asia, and America.

**Qualities and Uses.**—The agreeable acid fruits form the most striking character of this Order. The Gooseberry (*R. Grossularia*), the Black Currant (*R. nigrum*), the Red and White Currant (*R. rubrum*) are the most valuable kinds. The Black Currant is remarkable for the aromatic glands, which give a stimulant property. All contain malic acid. Other fruits of the Order resemble these, but are commonly either tasteless or excessively acid. Several species are showy garden shrubs, as *R. aureum*, *R. coccineum*, &c., in which the calyx is brightly coloured.

## ORDER LXXVII. HAMAMELACEÆ. WITCH-HAZELS.

*Class.* Discanthæ, *Endl.* *All.* Umbellales, *Lindl.* *Coh.* Rosales, *Benth. et Hook.*

434. *Diagnosis.*—Shrubs or trees, with alternate simple leaves and deciduous stipules: flowers in heads or spikes, often polygamous or monœcious: calyx adherent; petals narrow, valvate or involute in the bud, or absent: stamens twice as many as the petals, half sterile and scale-like, or numerous; pistil of 2 carpels, forming a 2-celled ovary, with 2 styles; ovules solitary in the cells or numerous: fruit a 2-beaked woody capsule with 1 seed in each of the two cells, bursting at the top; seeds albuminous.

### Illustrative Genera.

Tribe 1. Hamameleæ. *Dichlamydeous; 1 suspended ovule in each cell.*

Hamamelis, *L.*
Trichocladus, *Pers.*

Tribe 2. Fothergilleæ. *Monochlamydeous; ovary as in Tribe* 1.

Fothergilla, *L. f.*
Parrotia, *C. A. Mey.*

Tribe 3. Altingieæ. *Calyx often rudimentary; ovules several in each cell.*

Liquidambar, *L.*
Bucklandia, *R. Br.*
Rhodoleia, *Champ.*

**Affinities, &c.**—Lindley makes *Liquidambar* the type of a distinct Order, Altingiaceæ, associated with the Amentiferous Orders; but the relations between the genera above noted appear opposed to this. The flowers may be regarded as indicating an aberrant form, standing near Cornaceæ, from which they differ in their perigynous stamens, the fertile ones opposite the petals, their multiple style, alternate leaves, &c. They are also connected by Bruniaceæ with the Umbelliferæ. They approach closely to the Saxifrages, but have wood-cells marked with glandular dots and a large (not small) embryo, besides other points. The species are not numerous, but are widely diffused. *Hamamelis virginica*, Witch-Hazel, has oily edible seeds; its bark and leaves are astringent, and contain an acrid volatile oil. Various species of *Liquidambar* yield the pungent resin called Storax. *L. styraciflua* (North America) is an ornamental tree, the handsome 5-fid leaves of which turn red in autumn; its resin contains much benzoic acid. Most of the "liquid Storax" of commerce comes from the East, probably from *L. orientale* in the Levant, and *L. Altingia* in the Malay Islands. The bark of these trees is also acrid and bitter.

(Bruniaceæ are an Order of Heath-like shrubs, mostly found at the Cape of Good Hope, of unknown properties; in structure apparently connecting the Hamamelaceæ with the Umbelliferæ, having an epigynous disk, and the heads of flowers sometimes surrounded by involucral bracts; but the petals are valvate. They have some degree of affinity to Myrtaceæ also, thus bringing these into relation with the Caprifoliaceæ and allied Orders. Genera: *Brunia*, L.; *Staavia*, Thunb.)

## Order LXXVIII. UMBELLIFERÆ or APIACEÆ.

*Class.* Discanthæ, *Endl.* *All.* Umbellales, *Lindl.* *Coh.* Umbellales, *Benth. et Hook.*

435. *Diagnosis.*—Herbs, generally with fistular stems, alternate leaves sheathing at the base, generally deeply divided; the flowers in umbels; the tube of the calyx completely adherent to the ovary; the 5 petals and 5 stamens springing from the disk crowning the ovary and surrounding the base of the 2 styles (fig. 374); the fruit consisting of 2 separating, seed-like, dry carpels.

### *Character.*

***Calyx*** **adherent, the limb 5-toothed, ring-like, or undistinguishable.**

***Corolla*: *petals* 5, distinct, springing from the outside of the fleshy disk, mostly inflexed at the point, sometimes bifid, often unequal in size.**

***Stamens* 5, alternate with the petals and emerging with them, incurved in the bud.**

***Ovary*** inferior, 2-celled, composed of 2 coherent carpels, surmounted by a double fleshy disk or stylopod, from which project 2 divergent ***styles***; ***stigmas*** simple; *ovules* 1 in each cell, pendulous.

***Fruit*** consisting of 2 seed-like halves (*mericarps*) separating at the ***commissure***, remaining attached above to a forked carpophore (fig. 377), which was previously enclosed between them; each mericarp an indehiscent 1-seeded body, with the pericarp developed into longitudinal ridges (*juga*), 5 primary and sometimes 4 secondary, with intervening channels (*valleculæ*), in which often exist lines of oil-bearing tissue called *vittæ*; *embryo* in the base of abundant horny albumen.

Fig. 375.

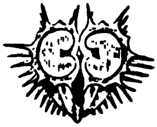


Fig. 374.

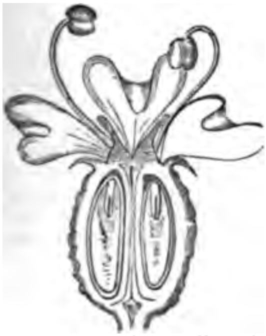


Fig. 376.

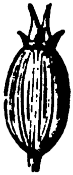


Fig. 377.

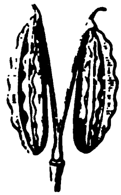


Fig. 374. Vertical section of the flower of *Fœniculum*.
Fig. 375. Cross section of the fruit of *Daucus*.
Fig. 376. Fruit of *Anthriscus*.
Fig. 377. Ripe fruit (mericarps) of *Conium*.

ILLUSTRATIVE GENERA.

Series 1. HETEROSCIADIÆ. *Umbels simple; vittæ none.*

Hydrocotyle, *Tournef.*
Mulinum, *Pers.*
Sanicula, *Tournef.*
Astrantia, *Tournef.*
Eryngium, *Tournef.*

Series 2. HAPLOZYGIÆ. *Umbels compound; primary ridges of fruit alone conspicuous; vittæ rarely absent.*

Echinophora, *L.*
Conium, *L.*
Smyrnium, *L.*
Cicuta, *L.*

Apium, *Hoffm.*
Helosciadium, *Koch.*
Ammi, *Tournef.*
Ægopodium, *L.*
Carum, *Koch.*
Bupleurum, *Tournef.*
Œnanthe, *Lam.*
Æthusa, *L.*
Fœniculum, *Adans.*
Silaus, *Bess.*
Crithmum, *Tournef.*
Angelica, *Hoffm.*
Archangelica, *Hoffm.*
Ferula, *L.*
Dorema, *Don.*
Peucedanum, *L.*
Heracleum, *L.*
Opoponax, *Koch.*

Series 3. DIPLOZYGIÆ. *Umbels compound; fruit with both primary and secondary ridges well marked.*

Coriandrum, *L.*
Cuminum, *L.*
Daucus, *L.*
Caucalis, *L.*
Thapsia, *L.*

**Affinities, &c.**—The arrangement of the genera above given is that of Bentham and Hooker, who greatly reduce the number of genera cited by other authors. By De Candolle the Umbellifers were grouped under three Suborders:—1. Orthospermeæ; albumen flat on the inner face: 2. Campylospermeæ; albumen involute, with a vertical groove on the inner face: 3. Cœlospermeæ; albumen inflexed above and below. The plants of this very extensive and important Order are in general readily recognizable by their inflorescence and fistular stems; but these characters are not always present, even in the indigenous forms; and it is instructive in this respect to examine the genera *Sanicula* and *Hydrocotyle*, where the umbels are little developed, and *Eryngium*, where the flowers are sessile and the involucral bracts so much developed as to give the umbels the appearance of the capitula of Compositæ. These deviations from the ordinary habit are still more striking in some of the exotic genera; for *Horsfieldia*, a Javan form, has capitulate heads arranged in panicles; and *Bolax*, an Antarctic genus, grows in a tufted manner, with imbricated leaves and nearly sessile umbels, so as to assume the outward appearance of some of the alpine species of *Androsace*. The essential character of the order lies therefore in the fruit, by which they are known from all other plants. The structure and arrangement of the ridges and vittæ upon the pericarp, together with the form of the albumen of the seed, furnish the characters by which the Order is subdivided; the latter character, although formerly regarded as primary, is now found to be inconstant.

The relations of the Umbelliferæ are closest with the other epigynous Calycifloræ with definite stamens, especially Araliaceæ (from which their fruit differs), the Rubiaceæ (which have monopetalous corollas and opposite leaves and interpetiolar stipules), and the Cornaceæ (where the leaves are partly opposite, the flowers tetramerous, and the fruit succulent). In habit, as well as in dicarpellary structure, some of the Umbelliferæ approach the Saxifragaceæ. The resemblances to Geraniaceæ seem rather superficial: the carpophore is of a very distinct character.

**Distribution.**—Abundant in the northern parts of Europe, Asia, and America; common upon the mountains of warmer regions, and again met with in the Southern hemisphere, but chiefly as dwarf and aberrant forms.

**Qualities and Uses.**—Several distinct classes of active secretions occur in the plants of this Order, which in some are extremely powerful, and in others slightly developed. The most important consist of acro-narcotic poisonous substances in solution in the watery juices; the second are gum-resinous substances contained in a juice belonging to special tissues, and becoming milky when exposed to the air; and the third are aromatic oils produced in all parts of the tissues, but especially developed in the vittæ of the pericarps. Many have the watery juices innocuous, and the gum-resinous secretion mild, so that they become esculent vegetables, which are rendered still more bland when they acquire a more succulent condition under cultivation. The absence of light has a remarkable effect in preventing the development of the aromatic principles, as is seen in blanched garden Celery and other cases.

A number of the poisonous kinds are indigenous, one of which, *Conium maculatum*, Hemlock, is in use in medicine as an anodyne. *Æthusa Cynapium*, Fool's Parsley, is a common weed; *Cicuta virosa*, Water Hemlock, is not uncommon (*C. maculata* of North America is equally poisonous); *Œnanthe crocata*, Hemlock Dropwort, *Œ. Phellandrium*, and other species are likewise noted as poisonous, although they appear to lose the property under certain circumstances. *Anthriscus sylvestris* and *vulgaris*, extremely common about hedges, are said to be poisonous. Accidents occur from the resemblance of the foliage of these plants to Parsley, and of the roots of *Œnanthe* and others to Parsneps.

The plants furnishing the antispasmodic gum-resins are mostly natives of warmer regions than the poisonous kinds, and some doubt exists as to the exact species which yield certain of these substances. Asafœtida is believed to be derived from *Ferula Asafœtida* (Persia and Afghanistan); *Ferula persica* probably furnishes some. *F. orientalis* (Morocco) yields an analogous resin. Sagapenum is supposed to be obtained from another species of *Ferula*. Gum Ammoniacum is from a Persian plant called *Dorema Ammoniacum* and *Diserneston gummiferum*. Opoponax is the resin of *Pastinaca Opoponax* (*Opoponax Chironum*). The source of Gum Galbanum is supposed to be *Ferula galbaniflua*.

The flavour of Celery (*Apium graveolens*), Parsley (*Petroselinum sativum*), Fennel (*Fœniculum vulgare*), Angelica (*Archangelica officinalis*), Eryngo (*Eryngium maritimum* and *campestre*), of the Carrot (*Daucus Carota*), and the Parsnep (*Pastinaca sativa*) depend on a volatile oil contained in the parenchymatous tissues, especially of the rind and leaves; but this oil is more concentrated in the vittæ of the pericarp, which renders the fruits of these plants still more powerfully aromatic, whence they are often used for flavouring in cooking; the fruits of the Caraway (*Carum Carui*), Dill (*Anethum graveolens*), Coriander (*Coriandrum sativum*), Anise (*Pimpinella Anisum*), Cummin (*Cuminum Cyminum*), and others are especially valued for these essential oils.

The roots of the Carrot and Parsnep, the root of *Arrachaca esculenta* (New Granada), the stem and petioles of Celery, when rendered very succulent by cultivation, retain only a moderate quantity of the aromatic oils, and are then chiefly valuable for their saccharine and mucilaginous qualities. Samphire, made into pickles, is *Crithmum maritimum*, a species growing on maritime rocks. The roots of Chervil (*Anthriscus Cerefolium*) were formerly eaten. The tubers of the species of *Bunium* are edible. Alexanders (*Smyrnium Olusatrum*) was formerly cultivated like Celery.

## ORDER LXXIX. ARALIACEÆ. THE IVY ORDER.

*Class.* Discanthæ, *Endl.* *All.* Umbellales, *Lindl.* *Coh.* Umbellales, *Benth. et Hook.*

436. *Diagnosis.*—Herbs, shrubs, or trees, with characters resembling those of Umbelliferæ, but usually with more than 2 styles, and the fruit 3- or several-celled, succulent or dry, with one albuminous seed in each cell.

### ILLUSTRATIVE GENERA.

Panax, *L.*
Aralia, *L.*
Hedera, *L.*
Adoxa, *L.*
Gunnera, *L.*
Helwingia, *Willd.*

**Affinities.**—The Araliaceæ stand very close to the Umbelliferæ, but may be distinguished by the ovary having more than 2 carpels. Most of the plants have also a valvate æstivation of the corolla, while it is imbricated in the Umbelliferæ: there are some exceptions to the rule in the latter Order; and *Adoxa* is an exception here. Seemann separates as a distinct Order, under the name Hederaceæ, all Umbelliferous plants with valvate petals and a fruit composed of two or more carpels. The true Araliads, according to this author, have imbricated petals. They are not so exclusively herbaceous as the Umbelliferæ, some being trees, and some climbing shrubs, which latter bring the Order into relation with the Vitaceæ. They are nearly allied to Caprifoliaceæ, which have a monopetalous corolla. *Adoxa* is remarkable for its stamens, which have a bipartite filament, each half bearing a separate anther-lobe; it also presents flowers with 4- and 5-merous corollas in the same inflorescence. *Gunnera*, an aberrant form, is in some cases diœcious, has but 2 petals and stamens, and a 1-celled, 1-seeded ovary; *G. scabra* is remarkable for its enormous leaves, as much as 8 feet in diameter, on stalks like those of *Rheum*. *Helwingia* is unisexual, and is made a type of a distinct Order by Decaisne and others. Its flowers are collected on the midribs of the leaves or bracts, from the adherence of the peduncle, somewhat as in *Tilia*. Seemann includes in Hederaceæ, on account of their valvate, not imbricate, petals, *Crithmum*, *Horsfieldia*, some species of *Hydrocotyle*, and some other plants usually placed in Umbelliferæ.

**Distribution.**—A considerable Order, distributed throughout all climates, and in all parts of the world.

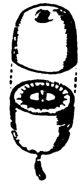
**Qualities and Uses.**—Aromatic and stimulant. The root of *Panax Ginseng* is highly valued by the Chinese as a stimulant; *P. quinquefolium* is exported to China from the United States as American Ginseng. *Aralia nudicaulis* (United States) is called Wild Sarsaparilla; *A. racemosa* yields an aromatic gum-resin. The astringent roots of *Gunnera scabra* are used for tanning, and the fleshy leaf-stalks are eaten. The berries of Ivy (*Hedera Helix*) are emetic and purgative. The wood of some of the East-Indian species is resinous and aromatic. The substance called Rice-paper, prepared by the Chinese, consists of thin slices of the pith of *Tetrapanax papyriferum*.

## ORDER LXXX. CORNACEÆ. THE DOGWOOD ORDER.

*Class.* Discanthæ, *Endl.* *All.* Umbellales, *Lindl.* *Coh.* Umbellales, *Benth. et Hook.*

437. *Diagnosis.*—Shrubs or trees (rarely herbaceous), almost always with opposite and exstipulate simple leaves; flowers 4–5-merous, sometimes diclinous; the tube of the calyx adherent to the 1–2-celled ovary, its limb minute; the petals (valvate in the bud), with as many stamens, inserted on the margin of an epigynous disk in the perfect flowers; style 1; a single anatropous ovule suspended from the top of each cell; the fruit baccate, 1–2-seeded (fig. 378); embryo nearly the length of the albumen, with large and foliaceous cotyledons.

Fig. 378.



Ripe fruit of *Cornus.*

### ILLUSTRATIVE GENERA.

Benthamia, *Lindl.* | Cornus, *Tournef.* | Aucuba, *Thunb.*

**Affinities.**—The chief distinctions from the Araliaceæ lie in the inflorescence, the tetramerous structure of the flower, the usually opposite leaves, the 2-carpellary ovary, and the simple style; from Umbelliferæ the first two characters divide them, together with the single style, and in most cases the habit; Caprifoliaceæ are distinguishable by the monopetalous corolla. Haloragaceæ differ in habit and distinct styles, but are connected with this group through *Gunnera.*

**Distribution.**—A small Order, the members of which are natives of the temperate parts of America, Europe, and Asia.

**Qualities and Uses.**—The bark of various species of *Cornus* is esteemed as a tonic and febrifuge; *C. florida* &c. are used in North America in place of Cinchona; *Cornus sanguinea,* Dogwood, is a common hedge shrub. *C. mascula,* the Cornelian Cherry, bears fruit, which is now little esteemed. *Aucuba japonica,* the variegated or "Cuba" Laurel of our shrubberies, is the female form of a diœcious Japanese plant, propagated in thousands by layers, but till lately never producing seeds, as the male plant was, till a few years ago, unknown in this country. Now, however, by artificially placing the pollen of the male flowers on the stigma of the female, or by the agency of insects, the scarlet olive-shaped berries are produced in profusion; and in this way numerous varieties have been raised from seed.

## SUBCLASS 3. COROLLIFLORÆ.

438. Dicotyledonous Flowering plants having both calyx and corolla, the latter mono- or gamopetalous and springing directly from the receptacle; the stamens mostly adherent to the corolla (epipetalous), rarely free and arising with the corolla from the receptacle.

Similar anomalies to those noted under the other Subclasses occur in some Orders which, on the whole, are Corollifloral. Thus, among Ericaceæ, the Suborder *Vacciniea* is properly Calycifloral, and the same thing occurs in Styracaceæ and elsewhere; among the Ericaceæ and Epacridaceæ we sometimes have the Thalamifloral condition, the petals being distinct and the stamens hypogynous. In Primulaceæ and Plumbaginaceæ polypetalous corollas occur, but with epipetalous stamens; and also apetalous flowers with hypogynous stamens, which, strictly speaking, would be Monochlamydeous. These (and many other cases might be noted) indicate the continual occurrence of "cross relations" between the groups of Orders, which render it very difficult to arrange the Orders satisfactorily, and show that any linear series is quite artificial.

## ORDER LXXXI. CAPRIFOLIACEÆ.

### THE HONEYSUCKLE ORDER.

*Class.* Caprifoliaceæ, *Endl.* *All.* Cinchonales, *Lindl.* *Coh.* Rubiales, *Benth. et Hook.*

439. *Diagnosis.*—Shrubs or rarely herbs, with opposite leaves and no stipules; the tube of the calyx adherent to the ovary; the stamens as many as (or one less than) the lobes of the tubular or rotate epigynous corolla, and attached to its tube; ovary 1–5-celled, often with 1 ovule in one cell and several in the others; style 1; stigmas 3 or 5; fruit indehiscent, dry or succulent, 1- or more-celled; seeds solitary or numerous; embryo in fleshy albumen.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Linnæa, *Gronov.* | Diervilla, *Tournef.* | Viburnum, *L.* |
| Symphoricarpus, *Dill.* | Lonicera, *Desf.* | Sambucus, *Tournef.* |

**Affinities.**—This Order is usually subdivided into two Suborders: 1. Lonicereæ, with a tubular, regular or irregular corolla, a filiform style, and seeds with a dorsal raphe; and 2. Sambuceæ, with regular rotate corollas, 3 sessile stigmas, and seeds with ventral raphe. It connects the monopetalous Rubiaceæ, Loganiaceæ, and their allies with the polypetalous Cornaceæ and Umbelliferæ. Through the *Escalloniea* it is also connected with the Saxifragaceæ.

**Distribution.**—A considerable Family, distributed chiefly in the northern parts of Asia, Europe, and America.

**Qualities and Uses.**—Some of the plants possess powerful purgative and emetic properties, as in the leaves of the Elder (*Sambucus nigra*), of the Guelder Rose (*Viburnum Opulus*), the Common Honeysuckle (*Lonicera Periclymenum*), and *Triosteum perfoliatum* (North America). The fruits seem destitute of this property, that of our Elder and others being made into wine; the berries of *Viburnum* are eaten in North America; and those of *Symphoricarpus*, the Snow-berry of our shrubberies, appear to be harmless. The fragrance and beauty of the flowers are marked characters of the Order. Besides Honeysuckles, species of *Lonicera* and *Caprifolium*, the Elder, the species of *Viburnum* (*V. Opulus*, grown in gardens for its balls of white *neuter* flowers, *V. Lantana*, the mealy Guelder Rose, *V. Tinus*, the Laurustinus shrub), *Symphoricarpus*, &c. are found in every shrubbery.

## ORDER LXXXII. RUBIACEÆ. THE MADDER ORDER.

*Class.* Caprifoliaceæ, *Endl.* *All.* Cinchonales, *Lindl.* *Coh.* Rubiales, *Benth. et Hook.*

440. *Diagnosis.*—Herbs, shrubs, or trees, with opposite entire leaves connected by interposed stipules, or in real or apparent whorls with stipules resembling the leaves; the calyx adherent to the 2–4-celled ovary; the stamens as many as the lobes (3–5) of the regular epigynous corolla, and attached to its tube; ovules anatropal; embryo albuminous.

### *Character.*

*Calyx* adherent, limb entire or 4–6-toothed.
*Corolla* monopetalous, regular, with a long tube, or rotate, its segments equal in number to the teeth of the calyx.

Fig. 379.

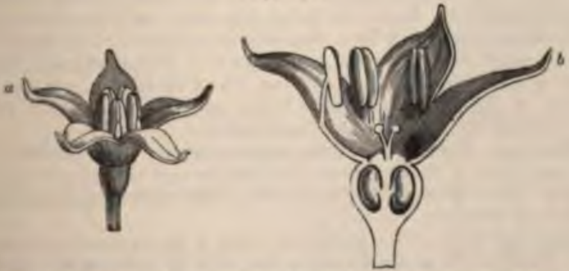


Fig. 379. *Rubia*: *a*, flower, nat. size, showing *obsolete* calyx, gamopetalous corolla, &c.; *b*, section of the flower.

*Stamens* equal in number to the lobes of the corolla, and attached in one line upon it, alternately with them.
*Ovary* inferior, usually 2-celled, with an epigynous disk; *style* single,

sometimes slightly divided; *stigmas* united or divided; *ovules* solitary, 2 or many in each cell.

*Fruit* splitting into two dry cocci, or indehiscent, and then dry and succulent, 2-celled, 2- or many-seeded; *seeds,* if definite, erect or ascending, or numerous on axile placentas; embryo in horny albumen.

### ILLUSTRATIVE GENERA.

Subord. 1. STELLATÆ. *Interpetiolar stipules leaf-like, forming whorls; ovary with* 1 *seed in each cell.*
- Galium, *L.*
- Rubia, *Tournef.*
- Asperula, *L.*
- Sherardia, *Dill.*

Subord. 2. COFFEÆ. *Stipules small; ovary with* 1–2 *seeds in a cell.*
- Opercularia, *A. Rich.*
- Coprosma, *Forst.*
- Spermacoce, *L.*
- Richardsonia, *Kunth.*
- Cephalanthus, *L.*
- Cephaelis, *Sw.*
- Psychotria, *L.*
- Coffea, *L.*
- Ixora, *L.*
- Morinda, *Vaill.*
- Guettarda, *Vent.*

Subord. 3. CINCHONEÆ. *Stipules small; ovary with numerous seeds.*
- Hedyotis, *Lam.*
- Rondeletia, *Bl.*
- Bouvardia, *Salisb.*
- Cinchona, *L.*
- Exostemma, *L. C. Rich.*
- Gardenia, *Ell.*

**Affinities.**—The Rubiaceæ are often divided into two Orders, Cinchonaceæ and Galiaceæ, or Stellatæ, the latter including all the genera with large foliaceous stipules, or, as they are termed, whorled leaves: the distinction does not appear to be sufficient. The presence of interpetiolar stipules, either small or imitating leaves, is the principal character separating this Order from Caprifoliaceæ, where, however, Lindley observes that they sometimes occur as monstrous growths. This Order also runs very close to Loganiaceæ, being chiefly distinguished by its inferior ovary; the Loganiaceæ thus connect it with Gentianaceæ and the allied Corollifloral Orders. The fruits of the *Stellatæ,* and of some of the *Coffeæ,* nearly relate them to the Umbelliferæ; from which, however, they may be at once known by the monopetalous corolla. *Opercularia,* an aberrant genus with a 1-celled, 1-seeded ovary, connects the Order with Dipsaceæ; and the inflorescence of some kinds, as *Cephalanthus, Richardsonia,* &c., approaches the condition of the capitula of that Order and of Compositæ; while in *Argyrophyllum* the stamens are syngenesious.

**Distribution.**—This is one of the largest Orders. The *Stellatæ* belong to the cool parts of the Northern hemisphere and the mountains of the Southern. The *Coffeæ* and *Cinchoneæ* are chiefly natives of warm climates, most of them tropical.

**Qualities and Uses.**—The Rubiaceæ form a very extensive group, and include plants with a considerable diversity of properties. Some are emetic and purgative; others febrifuge and tonic; others stimulant and restorative; some are astringent; a few have edible fruits; some yield valuable dye-stuffs; and fragrant or showy flowers abound in the Order. Among the powerfully emetic plants are the Ipecacuan, the officinal substance being the creeping rhizome of *Cephaelis Ipecacuanha. Psychotria emetica* furnishes a spurious kind called *black* or streaked Ipecacuan.

*Richardsonia scabra* and *emetica* yield *white* false Ipecacuan. *Chiococca densifolia* (Cahinca root) and *C. anguifuga* have similar properties, which are shared by the genera *Spermacoce*, *Manettia*, &c. Most of the above plants belong to Brazil. The two species of *Chiococca* above named are regarded as specifics against snake-bites; their emetic and purgative action is described as excessively powerful. Some species of *Cephaelis* and *Psychotria* are still more active, and are used as poisons for rats and mice in Brazil. Coffee consists of the seeds of *Coffea arabica*, two of which are produced in a succulent berry. It is believed to be a native of Abyssinia, perhaps also of Arabia, but is now widely diffused in cultivation in the East and West Indies and Brazil. The fruits of *Galium* are said to bear some resemblance to Coffee when roasted.

Cinchona, Peruvian or Jesuits' bark, is derived from several trees natives of the slopes of the Andes, at an elevation of about 7000–8000 feet, and many of which are now cultivated in India. The researches of Weddell, Howard, and others have determined the source of most of the kinds. *Cinchona Calisaya* gives Yellow or Calisaya bark; *C. succirubra*, Red bark; *C. nitida* and *micrantha*, Grey or Huanaco bark; *C. Condaminea* (var. *vera*), Crown or Loxa bark. The bark of various species of *Exostemma* is known as false Cinchona. Species of *Guettarda*, *Pinckneya*, *Rondeletia*, *Coutarea*, &c. have similar properties. The extract of the leaves of *Uncaria Gambir* is a powerful astringent, known as Gambeer among the Malays, and supposed to furnish part of the Catechu of commerce.

Among the fruits may be mentioned those of *Genipa* (Brazil and Madagascar), *Sarcocephalus esculentus*, the Sierra Leone Peach, &c. The berries of some *Coprosmæ* are eaten in Australia, and are called Native Currants.

Of the dyes, Madder, the roots of *Rubia tinctorum* (Europe), *R. cordifolia*, Munjeeth (Bengal), *R. Relbown* (China), and *R. angustissima* are the most important; *Oldenlandia umbellata*, used instead of Madder in the East Indies; species of *Morinda*, *Psychotria*, *Genipa*, *Condaminea*, &c. are of less importance. *Guettarda speciosa* furnishes what is called by cabinet-makers "Zebra-wood," from the West Indies.

Among the genera noticed in the list above, are found many of our favourite stove-plants, noted, like *Gardenia*, for fragrance, or, like *Ixora*, for their splendid blossoms and handsome foliage. Many species of *Galium* are common weeds with us, readily known by their star-like whorls of leaves and stipules.

## ORDER LXXXIII. VALERIANACEÆ.
### THE VALERIAN ORDER.

*Class.* Aggregatæ, *Endl.* *All.* Campanales, *Lindl.* *Coh.* Rubiales, *Benth. et Hook.*

441. *Diagnosis.*—Herbs with opposite simple or compound leaves and no stipules; the tube of the calyx adherent to the ovary, which has 1 fertile and 2 abortive or empty cells; the limb obsolete or forming a pappus; corolla epigynous, tubular, 3–6-lobed (lobes imbricate), sometimes spurred at the base; stamens 1–5, distinct, fewer than the teeth of the corolla, attached to its tube, alternate

with the lobes; seeds solitary, in the fertile cell of the dry, indehiscent, sometimes pappose fruit, pendulous, exalbuminous; radicle superior.

ILLUSTRATIVE GENERA.

Fedia, *Mœnch.* | Centranthus, *DC.* | Valeriana, *Neck.*

**Affinities.**—This Order approaches Dipsaceæ in general structure, sometimes having involucrate inflorescence; hence it is also related to Compositæ, Campanulaceæ, &c.; but the peculiar structure of the ovary is a very marked character, and the seed of Dipsaceæ is albuminous. The development and unrolling of the pappus of *Centranthus* and others, during the ripening of the fruit, is very singular: the corolla is surrounded by a thickened ring, which subsequently enlarges and expands into a crown of feathery processes.

**Distribution.**—An extensive Order, the members of which are distributed throughout the temperate parts of Europe, Asia, and America.

**Qualities and Uses.**—Many of the plants have strong aromatic properties, whence they are used as antispasmodic and tonic remedies. *Valeriana officinalis*, *Phu*, *celtica*, and *Saliunca* are all used; *V. sitchensis*, from Russian America, is said to be the most powerful. *Nardostachys Jatamansi* (India) is supposed to be the ancient Spikenard. *Fedia* or *Valerianella olitoria* is cultivated for salad, under the name of Lamb's Lettuce. *Centranthus ruber*, a showy plant, with abundant cymes of small rose-coloured flowers, is found in most gardens, and is naturalized in Kent.

## ORDER LXXXIV. DIPSACEÆ. THE SCABIOUS ORDER.

*Class.* Aggregatæ, *Endl.* *All.* Campanales, *Lindl.* *Coh.* Compositales, *Benth. et Hook.*

442. *Diagnosis.*—Herbs with opposite or whorled leaves, no stipules; the flowers in dense heads surrounded by an involucre as in Compositæ; the separate florets surrounded by special membranous involucels; calyx adherent, limb pappose; corolla epigynous, tubular, mostly irregular, 4–5-lobed, inserted on the calyx, imbricated in æstivation; stamens 4, sometimes half barren, attached to the tube of the corolla; anthers distinct; ovary 1-celled, with 1 pendulous ovule, simple style and stigma; fruit indehiscent; seed albuminous; radicle superior.

ILLUSTRATIVE GENERA.

Dipsacus, *Tournef.* | Scabiosa, *Röm. et Schult.*

**Affinities.**—Nearly related to Valerianaceæ on one hand, and to Compositæ on the other; distinguished from both by its involucels and albuminous seed; from Compositæ especially by the distinct anthers and pendulous seed.

**Distribution.**—The species number about 150, and are found most abundantly in Southern Europe and North and South Africa.

**Qualities and Uses.**—Some are said to be astringent. The Teazel, *Dipsacus fullonum*, a large Thistle-like plant, is of great importance, its dried capitula being used to comb up the nap on cloth, the hooked bracts not tearing the stuff like metal instruments. Many species of *Scabiosa* (Scabious) are cultivated for their beauty; two small-flowered species are natives of Britain.

(CALYCERACEÆ are a small Order of South-American plants, intermediate between Dipsaceæ and Compositæ, having the pendulous albuminous seed of the former, and anthers coherent below and free above, so as to approach the syngenesious character of the latter Order. Properties unknown. Genera: *Boopis*, Juss.; *Calycera*, Cav.).

## ORDER LXXXV. COMPOSITÆ OR ASTERACEÆ.

*Class.* Aggregatæ, *Endl.* *All.* Campanales, *Lindl.* *Coh.* Compositales, *Benth. et Hook.*

443. *Diagnosis.*—Herbs or half-shrubs with the flowers in dense heads (capitula) upon a common receptacle surrounded by an involucre; stamens 5 (rarely 4), inserted on the corolla, and with their anthers coherent into a tube surrounding the style; ovary inferior, 1-celled, with 1 erect ovule; seed exalbuminous.

### *Character.*

*Capitula* at the extremity of an enlarged peduncle surrounded by an involucre of bracts, and bearing perfect and imperfect florets closely packed, all similar, or of two kinds, those of the centre or disk and those of the circumference or ray; florets often accompanied by membranous scale-like bracts (*paleæ*).

*Calyx* adherent; limb obsolete, entire, or in the form of a circle of

Fig. 380.

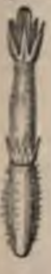


Fig. 381.

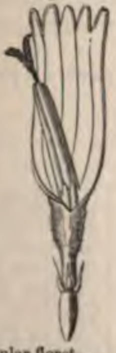


Fig. 382.

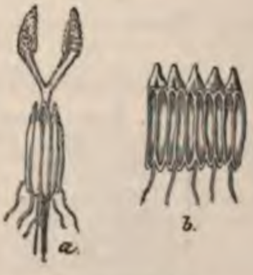


Fig. 383.

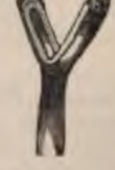


Fig. 380. Tubular floret. Fig. 381. Ligulate floret.

Fig. 382. Syngenesious stamens and pistil of Compositæ: *a*, in the natural position; *b*, the tube of anthers opened.

Fig. 383. Linear stigmas of Compositæ.

scales, bristles, or feathered or simple hairs (*pappus*), which is often persistent.

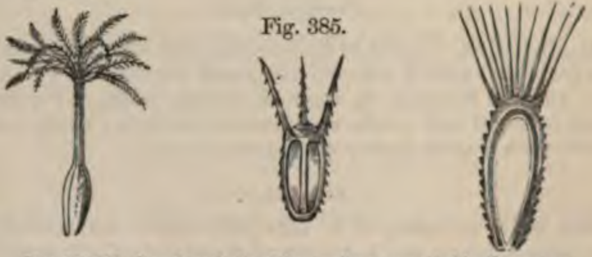
*Corolla* monopetalous, epigynous, tubular (fig. 380) and funnel-shaped, or ligulate (fig. 381), or bilabiate.

*Stamens* 5, alternate with the teeth of the corolla; *filaments* distinct; *anthers* cohering into a tube round the style (fig. 382).

*Ovary* inferior, 1-celled, with 1 erect ovule; *style* simple below, bifid at the apex, with a distinct *stigmatic* surface on each branch (figs. 382 & 383).

*Fruit* a cypsela (figs. 384–386), indehiscent, with 1 erect exalbuminous *seed*, often crowned by the pappus.

Fig. 384. Fig. 385. Fig. 386.



Figs. 384–386. Cypselous fruits of Compositæ surmounted by the pappus. (Fig. 386, vertical section, showing the erect seed.)

This extensive Order is divided into three Suborders.

1. Tubulifloræ. Florets all tubular and perfect, or only those of the centre (*disk*) perfect, while those of the circumference are tubular or ligulate, and female or neuter below its branches.

2. Labiatæfloræ. Florets with bilabiate corollas, perfect or unisexual.

3. Ligulifloræ. Florets all ligulate and perfect; juice milky.

### Illustrative Genera.

#### 1. Tubulifloræ.

Tussilago, *Tournef.*
Aster, *Nees.*
Bellis, *L.*
Solidago, *L.*
Inula, *Gærtn.*
Dahlia, *Cav.*
Zinnia, *L.*
Rudbeckia, *L.*
Helianthus, *L.*
Bidens, *L.*

Tagetes, *Tournef.*
Anthemis, *DC.*
Anacyclus, *Pers.*
Achillea, *Neck.*
Pyrethrum, *Gærtn.*
Chrysanthemum, *DC.*
Artemisia, *L.*
Gnaphalium, *Don.*
Arnica, *L.*
Senecio, *Less.*

Calendula, *Neck.*
Xeranthemum, *Tournef.*
Saussurea, *DC.*
Arctium, *Lam.*
Carlina, *Tournef.*
Centaurea, *Less.*
Cnicus, *Vaill.*
Carduus, *Gærtn.*
Serratula, *DC.*

### 2. LABIATÆFLORÆ.

Barnadezia, *L. fil.*
Mutisia, *L. fil.*
Printzia, *Cass.*
Anandria, *Siegesb.*
Nassavia, *Commers.*
Trixis, *P. Br.*

### 3. LIGULIFLORÆ.

Cichorium, *Tournef.*
Hypochæris, *L.*
Leontodon, *L.*
Tragopogon, *L.*
Sonchus, *L.*
Lactuca, *L.*
Taraxacum, *Juss.*
Crepis, *L.*
Hieracium, *Tournef.*

**Affinities.**—This Order, which is the most numerous, and, by some authors, regarded as the most perfect in the Vegetable Kingdom, is likewise very natural, its distinguishing features being very evident in almost every genus. From its nearest allies, Dipsaceæ and Calyceraceæ, it may be distinguished by the condition of the anthers and the ovule. The syngenesious condition, and, in some measure, the general structure of the florets, ligulate and tubular, indicate a near relation also to Lobeliaceæ and Campanulaceæ, wherein, however, the flowers are not only large and scattered, but the ovaries have more than one cell, with many seeds in each cell.

The subdivisions of this Order are differently given by different authors. The Orders of the Linnean Class Syngenesia, corresponding to Compositæ, are given in the Table of the Linnean Classification (page 185). Tubulifloræ, as above given, include the Corymbiferæ of some authors, in which the style of the perfect flowers is not swollen below the stigma, and the Cynareæ, where the outer florets are often neuter and the style is swollen below the stigmas. The tribes of the Compositæ usually accepted are those established by De Candolle on the condition of the style and its stigmatic lobes. The characters of the genera are chiefly derived from the conditions of the involucre, the cypselous fruit, and the pappus.

**Distribution.**—The species of this Order are more numerous than those of any other family, and are universally distributed, forming one-eighth of the Phanerogamia of Central Europe; the *Tubulifloræ* are most abundant in hot climates, the *Cichoraceæ* in cold. The *Labiatæfloræ* belong almost entirely to extratropical South America. In the Northern hemisphere the Compositæ are all herbaceous; in South America and some other parts of the southern hemisphere they are sometimes shrubby.

**Qualities and Uses.**—The plants of this Order are not generally characterized by any very powerful properties: bitterness is the prevailing quality, accompanied by aromatic secretions in the *Corymbiferæ*, and by a special lactescent juice in the *Cichoraceæ*, which often contains a more or less active narcotic principle.

Among *Corymbiferæ* may be noticed a number of genera possessing considerable importance. The *Artemisiæ*, or Wormwoods, are numerous; *A. Absinthium* and *pontica* are Wormwoods proper, and with some other species are used not only as anthelmintics, as their name indicates, but for preparing the bitter liqueurs called *Absinthe* or Wermuth; *A. Dracunculus* is the Tarragon, the leaves of which are used in salads and pickles; *A. Abrotanum* is Garden Southernwood, used also for its bitter flavour. Most of the other species have similar properties; the flower-heads of *A. Contra, Sieberi, pauciflora, Vahliana*, &c. are known on the Continent, under the name of Semen Cinæ or Semen Contra, as powerful vermifuges. *A. chi-*

*nensis* furnishes Moxa. *Anthemis nobilis*, the Camomile, *Matricaria Chamomilla*, and *Pyrethrum Parthenium* are valued for aromatic bitter and tonic properties; the species of *Achillea* are astringent, or in some cases pungent, which is still more the case with *Anacyclus Pyrethrum*, called Pellitory of Spain, and *A. officinarum*, the dried roots of which provoke an active flow of saliva, and are used as a remedy for toothache: in a fresh state these roots are acrid; and this is still more the case with *Maruta fœtida*. *Arnica montana*, a plant of the mountains of Central Europe, is narcotic-acrid and poisonous, except in small doses; its tincture has a powerful influence in exciting the circulation beneath the skin without producing vesication. *Doronicum Pardalianches* is said to have similar properties, as also some species of *Inula*; *Inula Helenium*, however, is merely aromatic and tonic; it is known under the name of Elecampane.

Some species of *Eupatorium*, including our native *E. cannabinum*, are emetic and purgative; *E. Ayapana* (Brazil) has a reputation as a local and internal application for snake-bites. Matico is said to be obtained from *E. glutinosum*, though most of it is the produce of *Artanthe elongata*, a Piperaceous plant; its leaves are used as a styptic.

The seeds of some of the *Corymbiferæ* contain much fixed oil. The seeds of the Sunflower (*Helianthus annuus*) are well known on this account; and *Madia sativa* (Chili) has become an object of cultivation in France and Germany for the sake of the oil expressed from its seeds, its "oil-cake" being also valuable for cattle. The esculent tubers called Jerusalem or *Girasole* Artichokes are furnished by *Helianthus tuberosus*; the analogous tubers of the Dahlia (*Dahlia variabilis*) are not available in this way on account of a strong and unpleasant flavour which exists in them. *Tussilago Farfara*, or Coltsfoot, which is mucilaginous and bitter, was formerly in repute for affections of the chest.

The *Cynareæ*, or thistle-like Compositæ, are equally varied in the concentration of their qualities. The root of *Carlina acaulis* is said to be a violent purgative, and that of *C. gummifera* is known as an anthelmintic. The Burdock (*Arctium Lappa*), the Marigold (*Calendula officinalis*), *Centaurea Calcitrapa*, and other allied plants were formerly esteemed as febrifuges, diuretics, and alteratives, but have gone out of use. The Costus, celebrated by the ancients for its virtues, is supposed to be the root of *Aucklandia Costus* (Cashmere). *Carthamus tinctorius*, Safflower, is used in dyeing and in the manufacture of true rouge; the flowers of *Calendula officinalis* are used to adulterate Saffron. *Serratula tinctoria* is also used in dyeing yellow and green. The Globe Artichoke is the fleshy receptacle, with its bracts, of *Cynara Scolymus*; Cardoons are the blanched stems and petioles of *Cynara Cardunculus*.

The *Labiatæfloræ* are sometimes aromatic, bitter, or mucilaginous. The leaves of *Printzia aromatica* are used as a Tea at the Cape of Good Hope; those of *Anandria discoidea* are used by the Chinese as the Coltsfoot is in Europe.

The *Cichoraceæ* include several plants of note: the different kinds of Lettuce, *Lactuca virosa*, *Scariola*, *sativa* (the Garden Lettuce), contain a milky juice which has narcotic properties; when evaporated to dryness it forms a kind of gum, called by druggists Lactucarium, which is occasionally used as a sedative. The Garden Lettuce loses much of its bitterness, and, at the same time, of its narcotic properties, in cultivation. The Dandelion, *Leontodon Taraxacum* (or *Taraxacum Dens Leonis*), has also a milky juice, which is valued for its medicinal properties as a diuretic and alterative, with some sedative qualities; its roots, and still more those of Chicory or Succory (*Cichorium Intybus*), are used, roasted, to adulterate coffee. Besides the Lettuce we have other esculent vegetables in this Suborder: *Cichorium Endivium* furnishes the Salad Endive (blanched by exclusion of light); Scorzonera is the root of *Scorzonera hispanica*, other species of which are used in like manner in different countries; Salsafy is the root of *Tragopogon porrifolius*, or Goat's-beard.

The Compositæ include a vast number of cultivated plants. The Dahlia (*D. variabilis*), the Chrysanthemum (*Pyrethrum sinense, indicum*), the Cinerarias (*Senecio cruenta, Tussilaginis, Heritieri*), the China Aster (*Callistemma hortense*) are florist's flowers remarkable for the number and beauty of their varieties. The Everlasting-flowers, or *Immortelles*, are mostly species of *Gnaphalium*, together with *Helichrysum, Aphelexis*, &c. Our native Thistles are species of *Carduus, Onopordum*, &c.

## ORDER LXXXVI. LOBELIACEÆ.

*Class.* Campanulinæ, *Endl.* *All.* Campanales, *Lindl.* *Coh.* Campanales, *Benth. et Hook.*

444. *Diagnosis.*—Herbs or shrubs with a milky juice, alternate leaves, and scattered flowers; corolla irregular, epigynous, monopetalous, split down to the base on one side; the 5 stamens free from the corolla and united into a tube, often by their filaments, and always by their anthers; ovary inferior, 1–3-celled; style 1; stigma 2-lipped, surrounded by a fringe of hairs; seeds numerous, albuminous.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Lobelia, *L.* | Siphocampylus, *Pohl.* |

**Affinities.**—The relations of this Order to Compositæ are close, as is seen when we compare the flowers with ligulate florets of the *Cichoraceæ*: the structure of the ovary, however, as well as of the inflorescence, divides them. With Campanulaceæ they are connected through the tubular florets of Compositæ, which resemble the flowers of Campanulaceæ, except in the structure of the ovary, which brings the Campanulaceæ still nearer to Lobeliaceæ. The fringe round the stigma is analogous to the hairs of the style of Campanulaceæ, and perhaps also to the indusium of Goodeniaceæ. Some Lobeliaceæ have their petals distinct.

**Distribution.**—A rather large Order, the members of which are chiefly distributed throughout tropical and subtropical regions.

**Qualities and Uses.**—The milky juice is acro-narcotic; the species of *Lobelia* are more or less poisonous, producing effects analogous to those of Tobacco. *Lobelia inflata* is used in small doses for spasmodic asthma; it acts sometimes as an emetic, but produces great depression of the pulse, perspiration, and, in large doses, death. Most of the species are acrid when fresh; *L. urens* produces vesication of the skin. *Tupa Feuillei* (Chili) yields a violent poison. *Isotoma longiflora* is vesicatory, and, taken internally, produces death from violent and uncontrollable purging. The milky juices contain Caoutchouc. Many species of *Lobelia* and *Siphocampylus* are cultivated for their showy flowers.

(GOODENIACEÆ constitute an Order of plants allied to the Lobeliaceæ, the Stylidiaceæ, and the Campanulaceæ, but especially distinguished by the remarkable structure of the upper part of the style, which is expanded into a kind of cup or purse, concealing within it the stigmatic surface, and closing over the pollen after fertilization. Most of the Goodeniaceæ are Australian and Polynesian; a *Scævola* occurs in North-western India and in Africa; another genus, *Selliera*, is South-American. Their properties are unimportant. *Leschenaultia formosa*, *cærulea*, and other species are cultivated on account of the beauty of their flowers.)

(BRUNONIACEÆ, consisting of two species of *Brunonia*, Australian plants, agree with Goodeniaceæ in the structure of the style, but are sometimes separated from them on account of the superior position of the ovary. Their capitulous inflorescence approaches that of Compositæ. They have no known properties.)

(STYLIDIACEÆ constitute a small Order of plants related to the Goodeniaceæ and the Campanulaceæ, but are distinguished by and remarkable for the gynandrous structure of the flowers, the filaments being adherent to the style into a column surmounted by the anthers which overlie the stigma. This column exhibits the irritability met with here and there in Flowering Plants: in *Stylidium* it hangs over on one side of the flower; but when touched it rises up and springs over to the opposite side, at the same time opening its anthers and scattering the pollen. The *Stylidia* are chiefly from Australia; a few others are scattered in the East Indies; the *Forsteræ* belong to New Zealand and the Straits of Magellan. They have no known properties.)

## ORDER LXXXVII. CAMPANULACEÆ. BELL-FLOWERS.

*Class.* Campanulinæ, *Endl.* *All.* Campanales, *Lindl.* *Coh.* Campanales, *Benth. et Hook.*

445. *Diagnosis.*—Herbs with a milky juice, alternate leaves, and mostly scattered flowers; calyx adherent to the ovary; corolla regular, epigynous, bell-shaped, valvate in æstivation; stamens 5, free from the corolla, mostly distinct or coherent just below the base of the distinct anthers; ovary 2–5-celled; style 1, hairy; stigma simple or lobed; capsule many-seeded, dehiscent by lateral orifices or valves at the top; seeds with fleshy albumen.

ILLUSTRATIVE GENERA.

Jasione, *L.*
Prismatocarpus, *A. DC.*
Phyteuma, *L.*
Campanula, *L.*

**Affinities.**—The Campanulaceæ have many points of agreement with the Compositæ, the flowers resembling the tubular florets of that Order in the corolla, inferior position of the ovary, and number and position of the stamens; but the anthers are distinct or only united at the base, and the ovary is more than 1-celled, and contains many seeds; in *Jasione* and *Phyteuma* the flowers are in capitula, almost like those of Compositæ. They are only separated from Lobeliaceæ by the regularity of their flowers, the globular (not elliptical) pollen-grains, and the peculiar hairs of the style; which points of structure likewise separate them from Goodeniaceæ and Stylidiaceæ. On the other hand they approach *Vaccinieæ*, from which they differ in the number of the stamens and their porous dehiscence, the style, and the habit.

**Distribution.**—A large Order, the members of which belong mostly to the temperate parts of the Northern hemisphere.

**Qualities and Uses.**—The milky juice has properties analogous to that of the Compositæ, and is sometimes rather acrid; but the young roots and shoots, especially when cultivated, are often edible; Rampions are the roots of *Campanula Rapunculus*; *Specularia Speculum* and other species have been used in salads. The *Campanulas*, commonly known as Canterbury Bells, Hair-bells, &c., are numerous in cultivation; and other genera have also handsome flowers.

## ORDER LXXXVIII. ERICACEÆ. THE HEATH ORDER.

*Class.* Bicornes, *Endl.* *All.* Ericales, *Lindl.* *Coh.* Ericales, *Benth. et Hook.*

446. *Diagnosis.*—Shrubs, or sometimes herbs, with regular or nearly regular flowers; corolla gamo- or polypetalous, hypogynous or epigynous (*Vaccinieæ*); stamens as many, or twice as many as the petals of the 4–5-lobed or 4–5-petalous corolla, free from the corolla, hypogynous or epigynous; anthers 2-celled, commonly with appendages, and opening by terminal chinks or pores (figs. 388, 389); style 1; ovary 3–10-celled; seeds small, anatropous; embryo small or minute, in fleshy albumen.

Fig. 388.

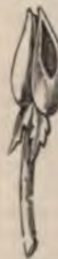


Fig. 387.

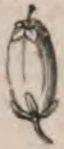


Fig. 389.

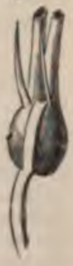


Fig. 387. Flower of *Erica*.
Fig. 388. Stamen of *Erica*.
Fig. 389. Stamen of *Vaccinium*.

The Ericaceæ are divisible into four very distinct Suborders, which are sometimes ranked as Orders.

1. VACCINIEÆ. Shrubby, or more or less woody herbs, with an adherent calyx, monopetalous epigynous corolla, epigynous stamens, 2-parted anthers opening by pores, containing 4-nate pollen-grains;

the inferior ovary becoming a berry surmounted by the teeth of the calyx.

2. Ericineæ. Shrubs or small trees, with a free calyx; a monopetalous or polypetalous corolla springing with the stamens from the receptacle; anthers opening by pores.

3. Pyroleæ. Woody herbs with evergreen foliage; calyx free; corolla of 5 distinct hypogynous petals; stamens hypogynous; anthers porous; seeds with a loose cellular testa and minute nucleus.

4. Monotropeæ. Fleshy herbs with scale-like leaves, destitute of green colour; calyx free; corolla mono- or polypetalous; stamens hypogynous; pollen simple.

### Illustrative Genera.

#### 1. Vaccinieæ.

Oxycoccus, *Tournef.* | Vaccinium, *L.*

#### 2. Ericineæ.

Tribe 1. ERICEÆ. *Fruit loculicidal, rarely septicidal or baccate; buds naked.*

Erica, *L.*
Andromeda, *L.*
Arbutus, *Tournef.*
Arctostaphylos, *Adans.*

Tribe 2. RHODODENDREÆ. *Fruit capsular, septicidal; buds scaly, cone-like.*

Azalea, *L.*
Rhododendron, *L.*
Ledum, *L.*

#### 3. Pyroleæ.

Chimaphila, *Pursh.* | Pyrola, *Tournef.*

#### 4. Monotropeæ.

Monotropa, *Nutt.* | Schweinitzia, *Ell.* | Pterospora, *Nutt.*

**Affinities.**—The Suborders brought together under this head are connected by the general plan of structure; but the details are subject to wide variation, not only including monopetalous and polypetalous conditions, but even hypogynous and epigynous. By many authors these subdivisions are ranked as distinct Orders. The *Vaccinieæ*, with their inferior ovary, stand, if separated, among the epigynous Calycifloral Orders, near Campanulaceæ or Cinchonaceæ; consequently they form a connecting link between the Calycifiorals and Corollifiorals, indicating the artificiality of this division; they even appear related to the perigynous Calycifiorals by *Escallonieæ* in Saxifragaceæ. The *Ericineæ* differ from the *Vaccinieæ* principally in the superior ovary and hypogynous corolla; and the stamens are here nearly if not quite hypogynous, which, with the many-celled ovary, divides them from Gentianaceæ and allied Orders. The *Ericineæ* are nearly allied to the Epacridaceæ; but these have 1-celled anthers. The *Pyroleæ* have the sepals and petals more or less distinct, are more herbaceous in habit than the foregoing, and their seeds are remarkably different; *P. aphylla*, a plant devoid of green colour, and with leaf-scales in place of leaves, connects this Suborder with *Monotropeæ*, which, however, differ in the dehiscence of the anthers, and in having the minute embryo at the apex instead of the base of the fleshy albumen. Some doubt exists whether the last Suborder are really parasitical plants: they grow among the fibrils of the roots of trees, and have all the appearance of parasites, but, with Duchartre, we have never been able to see any union in *Monotropa*. In the character of habit they resemble Orobanchaceæ; but we do not consider this a strong sign of affinity in Flowering plants.

**Distribution.**—A large Order, the members of which are generally diffused in temperate climates over heathy and boggy tracts, in subalpine and alpine localities, all over the world—the *Rhododendra* especially in India, and the *Befariæ* in South America. Remarkably abundant at the Cape of Good Hope.

**Qualities and Uses.**—The general character is astringency. The fruits of various *Vaccinieæ* and *Ericeæ* are edible—as *Oxycoccus palustris* and *O. macrocarpa* (the European and North-American Cranberries), *Vaccinium Myrtillus* (the Bilberry), *V. Vitis-Idæa* (the Red Whortleberry), and *V. uliginosum* (the Black Whortleberry), *Gaultheria procumbens*, *G. hispida* (Tasmania), &c. But others are dangerous or even narcotic poisons, and this extends to the foliage of such kinds, especially species of *Rhododendron*, *Azalea*, *Andromeda*, *Kalmia*, &c. Uva-Ursi leaves, *Arctostaphylos Uva-Ursi*, are mixed with Tobacco by the North-American Indians, and are esteemed as astringents; those of some *Pyroleæ*, as *Chimaphila umbellata*, American Wintergreen, are used as diuretics. Oil of Wintergreen, known as an antispasmodic agent, and used in perfumery, is obtained from the fruit of *Gaultheria procumbens*. A vast number of species of *Erica*, *Rhododendron*, *Azalea*, &c., with numerous varieties and hybrids, are objects of cultivation on account of the peculiarity and beauty of their flowers. They especially constitute what are called "American Plants" by gardeners, the American *Rhododendra*, *Azaleæ*, and *Kalmiæ*, &c. being those which first strongly occupied the attention of florists. Some of the East-Indian *Rhododendra* are epiphytes.

(EPACRIDACEÆ are closely related to Ericaceæ, but are distinguished by the one-celled anthers opening by a chink; the filaments are also commonly adherent to the corolla. The Order is commonly divided into two Tribes: 1. Stypheliеæ, with one ovule in each cell of the ovary, and fleshy fruits; and 2. Epacreæ, with numerous ovules in each cell of the ovary, and capsular fruit. They are peculiar to Australia, the Indian archipelago, and the South-Sea Islands, occurring in great abundance, in the same way as the *Ericeæ* do at the Cape of Good Hope. They do not appear to possess any active properties: many of them bear succulent berries; and some of them are eaten, as those of *Lissanthe sapida*, *Astroloma humifusum*, the Tasmanian Cranberry, &c. Many of the Epacridaceæ are in cultivation on account of the beauty of their flowers.)

## ORDER LXXXIX. OLEACEÆ. THE OLIVE AND ASH ORDER.

*Class.* Contortæ, *Endl.* *All.* Solanales, *Lindl.* *Coh.* Jasminales, *Benth et. Hook.*

447. *Diagnosis.*—Trees or shrubs with opposite and pinnate or simple leaves; flowers with a 4-cleft (or sometimes obsolete) calyx; a regular 4-cleft or nearly or quite 4-divided, hypogynous corolla, the lobes of which are valvate in the bud, or sometimes apetalous; stamens 2–4, mostly 2, and fewer than the lobes of the corolla (figs. 390, 391); ovary 2-celled, with 2 suspended ovules in each cell; fruit fleshy or capsular, often 1-seeded by abortion; seeds with abundant fleshy albumen; radicle superior.

Fig. 390.

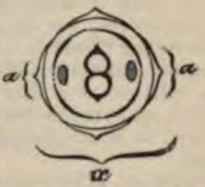


Fig. 391.

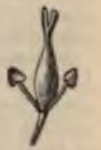


Fig. 390. Diagram of flower of Lilac (*Syringa*): *x*, bract; *a*, *a*, bracteoles.

Fig. 391. Flower of *Fraxinus*.

### ILLUSTRATIVE GENERA.

| Tribe 1. OLEÆ. *Fruit fleshy.* | Tribe 2. FRAXINEÆ. *Fruit dry, sometimes samaroid.* |
|---|---|
| Olea, *Tournef.* | Fraxinus, *Tournef.* |
| Phillyrea, *Tournef.* | Ornus, *Pers.* |
| Ligustrum, *Tournef.* | Syringa, *L.* |

**Affinities.**—The relations of this Order are rather obscure. Some authors connect them with the Jasminaceæ; but although some of the genera approach that Order in structure, they appear to be distinct in their valvate corolla, adnate (dorsifixed) anthers, pendulous ovules, and the nature of the albumen. The Salvadoraceæ are also to be regarded as a neighbouring family. Lindley thinks the Order allied to Solanaceæ.

**Distribution.**—A small Order, the members of which are chiefly found in temperate climates.

**Qualities and Uses.**—The most important plant of the Order is the Olive (*Olea europæa*), so largely cultivated for the bland oil expressed from the fleshy pericarps. *Ornus europæa*, *O. rotundifolia*, and *Fraxinus excelsior* have a sweet juice which hardens into the substance called Manna. *Fraxinus excelsior* is the common Ash-tree, so valuable for its tough wood; it only produces Manna in a warmer climate than Britain; its bark, as well as that of the Olive and the Garden Lilac (*Syringa vulgaris*), has decided febrifuge qualities. The leaves of the Ash act like senna. The flowers of *Olea fragrans* are used in China to flavour Tea.

This Order contains several of the commonest flowering shrubs of our gardens, the Lilac (*Syringa*), Privet (*Ligustrum*), *Phillyrea*, *Chionanthus*, &c.

## ORDER XC. JASMINACEÆ. THE JASMINE ORDER.

*Class.* Contortæ, *Endl.* *All.* Echiales, *Lindl.* *Coh.* Jasminales, *Benth. et Hook.*

448. *Diagnosis.*—Shrubs, often with twining stems; leaves opposite or alternate, mostly compound; calyx and corolla hypogynous, 5–8-parted, corolla imbricated in the bud; stamens 2, projecting from the tube of the corolla; ovary superior, 2-lobed, 2-celled, with 1–4 erect ovules in each cell; fruit a berry or capsule; seeds with little or no albumen.

### ILLUSTRATIVE GENERA.

Jasminum, *L.* | Nyctanthes, *Juss.*

**Affinities.**—This Order is distinguished from the Oleaceæ by the imbricated æstivation of the corolla, the erect ovules, and the small quantity of albumen in the seeds, besides the number of the organs in the floral envelopes, which is seldom a multiple of the stamens: most authors place it near Oleaceæ, others near Apocynaceæ and Ebenaceæ; but Lindley thinks it has little connexion with them and really approaches more closely to Verbenaceæ.

**Distribution.**—The Order is not very extensive; the major part of the plants are East-Indian; a few occur scattered, two even in South Europe.

**Qualities and Uses.**—The leaves and roots appear to possess a certain acridity; but the most remarkable quality is the fragrance of the flowers of many kinds, from the presence of a volatile oil. *Jasminum officinale*, *J. grandiflorum*, and *J. Sambac* especially yield this. *Nyctanthes Arbor tristis* is also exceedingly fragrant, but in the night-time only; its corollas yield an orange dye.

(COLUMELLIACEÆ consist of a few species of Mexican or Peruvian plants, which have been supposed to approach Jasminaceæ, or still more closely to Gesneraceæ and Rubiaceæ; but their structure is not well made out. They have an adherent calyx, epigynous corolla, two stamens with sinuous anthers, and an inferior 2-celled ovary with numerous ovules. Seeds albuminous; embryo minute.

(SALVADORACEÆ are a small Order of shrubs or small trees with opposite leathery leaves, panicled small flowers; calyx, corolla, and stamens 4-merous, hypogynous; ovary superior, 1-celled; stigma sessile; ovule 1, erect; fruit fleshy, 1-seeded, and the seed without albumen. It is related by its 4-nary structure to Oleaceæ and to Plantaginaceæ, having a membranous corolla like the last; also resembling Plumbaginaceæ in habit. The species are found in India, Asia Minor, and North Africa. The most important is *Salvadora persica*, supposed to be the Mustard-tree of the Bible, its fleshy fruit having an aromatic odour and tasting like garden-cress. The bark of its root is used in India as a vesicatory. The leaves of *S. indica* are purgative.)

## ORDER XCI. PLANTAGINACEÆ.

*Class.* Plumbagines, *Endl.* *All.* Cortusales, *Lindl.* *Coh.* Plantaginales, *Benth. et Hook.*

449. *Diagnosis.*—Chiefly herbs with undeveloped stems and tufts of leaves spreading more or less on the ground; flowers spiked, regular, 4-merous, the 4 stamens attached to the tube of the hypogynous dry and membranous monopetalous corolla, alternating with its lobes; the filaments long and slender, and the anthers versatile; ovary simple, but spuriously 2- or 4-celled by temporary adherence of the angles of the free central placenta to the walls; ovules 1, 2, or numerous, peltate; style and stigma simple, the latter rarely cleft; capsule membranous, dehiscence circumscissile; seeds 1, 2, or many, albuminous; the testa mucilaginous.

### ILLUSTRATIVE GENERA.

Littorella, *L.* | Plantago, *L.*

**Affinities.**—This Order appears to find its nearest relatives in Plumbaginaceæ and Primulaceæ, from which, however, the position of the stamens, alternating with the lobes of the corolla, distinguishes it, in addition to other characters noticed under those Orders. The supposed affinity to Amaranthaceæ and Chenopodiaceæ does not appear well made out. In *Littorella* there is a tendency to abortion in one or other set of essential organs, producing a diclinous condition.

**Distribution.**—A not very extensive group, the species of which are generally diffused, but most abundant in temperate climates.

**Qualities and Uses.**—The foliage is slightly bitter and astringent, but the plants are not now regarded on this account. The seeds of many species of *Plantago*, such as *P. Psyllium*, *arenaria*, *Cynops*, &c., were much used formerly on the Continent, under the name of Semen Psyllii and S. Pulicariæ, or Flea-seed, for making mucilaginous drinks like those prepared from linseed; the spikes of the fruit of *P. major* are much gathered in the green state under the name of Plantain, for feeding caged birds. *P. major*, *minor*, and *lanceolata*, called Plantains or Road-weeds, are among the commonest of our weeds on road-sides, in meadows, and all undisturbed ground where the soil is not very light.

## ORDER XCII. PLUMBAGINACEÆ. THE THRIFT ORDER.

*Class.* Plumbagines, *Endl.* *All.* Cortusales, *Lindl.* *Coh.* Primulales, *Benth. et Hook.*

450. *Diagnosis.*—Maritime or mountain herbs or under-shrubs, often with undeveloped stems and clustered leaves; flowers regular, 5-merous, with a plaited calyx; the 5 stamens opposite the separate petals or the lobes of the monopetalous corolla; the free ovary 1-celled, with a solitary

ovule hanging from a long funiculus which arises from the base of the cell; styles 5, rarely 3 or 4; fruit either utricular or dehiscent by valves above; seed with a simple testa and little albumen.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Statice, *L.* | Plumbago, *Tournef.* |

**Affinities.**—This Order is strongly characterized by the peculiar attachment of its ovule: this, with the numerous styles, separates it from the Primulaceæ, which it approaches in the position of the stamens and some other points; the same characters, with the position of the stamens, distinguish it from Plantaginaceæ; and these marks, with the plaited calyx, isolate it from all the other Corollifloral Orders, among which it claims a place in spite of the occasionally polypetalous or even apetalous condition.

**Distribution.**—A rather large group; some kinds are found all over the world on the sea-shore; others are more local in similar habitats, in salt-marshes and in saline steppes, while others, again, belong to alpine regions.

**Qualities and Uses.**—The properties are either bitter and astringent, or acrid and caustic. The roots of *Statice caroliniana* are powerfully astringent; those of *Plumbago europæa, zeylanica, scandens,* and others are very active blistering-agents when fresh; that of *P. europæa* is used dried as a remedy for toothache. *P. toxicaria* is said to furnish a poison in Mozambique. The Garden Thrift (*Armeria vulgaris*), commonly used for edging, like Box, is said to be an active diuretic: the dried flowers are used for this purpose. Small doses of the root of *Plumbago europæa* are said to act as an emetic.

The flowers of many of the Plumbaginaceæ, especially species of *Statice,* are very handsome, and many are cultivated on this account.

## ORDER XCIII. PRIMULACEÆ. THE PRIMROSE ORDER.

*Class.* Petalanthæ, *Endl.* *All.* Cortusales, *Lindl.* *Coh.* Primulales, *Benth. et Hook.*

451. *Diagnosis.*—Herbs with opposite or alternate simple leaves and regular, perfect flowers; the stamens as many as the lobes of the monopetalous (rarely polypetalous) hypogynous corolla, and attached opposite to them in the tube; ovary 1-celled, with a free central placenta bearing several or numerous albuminous seeds, a simple style, and a capitate stigma.

### *Character.*

*Calyx* 5- or rarely 4-cleft, free or half-adherent, regular, persistent.

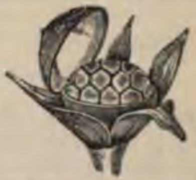
*Corolla* hypogynous, monopetalous, and the limb regularly 5-, or rarely 4-cleft; or more rarely composed of separate petals, or absent.

*Stamens* equal in number to the petals or lobes of the corolla and adherent to them; or in apetalous flowers hypogynous and alternating with the teeth of the calyx.

*Ovary* 1-celled, with a free central placenta bearing many ovules; *style* single; *stigma* capitate.

*Fruit*: a capsule opening by valves, more rarely circumscissile (fig. 392), many-seeded; *seeds* peltate; the embryo in fleshy albumen.

Fig. 392.



Capsule of *Anagallis* opening by circumscissile dehiscence.

### ILLUSTRATIVE GENERA.

Primula, *L.*
Cyclamen, *Tournef.*
Glaux, *Tournef.*
Lysimachia, *Mœnch.*
Anagallis, *Tournef.*
Samolus, *Tournef.*

**Affinities.**—This is an Order which strongly attracts the attention of Structural Botanists on account of the peculiarities and anomalies which it presents. It is one of those in which the free central placenta (§ 226) is most distinctly seen, forming an exception to the very general rule of the placentas arising from the margins of the carpels. In the next place the position of its stamens opposite the petals is an exception to the rule of alternation of the organs of successive floral whorls, to be explained only by supposing an intermediate whorl of stamens to be suppressed (in favour of which is found the condition of *Samolus*, *Lysimachia ciliata*, and others, where five teeth, which may be abortive stamens, alternate with the lobes of the corolla), or by the hypothesis of *chorisis* (§§ 149, 152). In *Samolus* we have the calyx partially adherent to the ovary. In some foreign genera the petals are either nearly or quite distinct. In *Trientalis europæa* the lobes of the calyx, corolla, and the number of stamens vary from 5 to 9. In *Glaux* the corolla is absent, and the calyx coloured.

The relations to Plumbaginaceæ are very close, both in the structure and the habit of many kinds, as between *Androsace* and some *Primulæ* and *Armeria*, &c.; but the solitary ovule of that family is a distinctive character. The Primulaceæ are still nearer to the exotic Order Myrsinaceæ as regards the structure of the flowers; but those are trees or shrubs with berry-like fruits, and have minor characters of distinction noticed under that Order. On the other hand, they approach Solanaceæ in habit, but differ much in structure.

**Distribution.**—A considerable family, the species of which are chiefly found in temperate and cold parts of the Northern hemisphere, in alpine regions or the sea-shore when in lower latitudes.

**Qualities and Uses.**—The Cowslip (*Primula veris*) and other species appear to possess sedative properties. The *Soldanellæ* are slightly purgative. The Cyclamens have a fleshy tuber which is more or less acrid; and *Cyclamen europæum* is said to be a drastic purgative.

The most remarkable quality is perhaps the beauty of the flowers, for which a great number are cultivated, especially species of *Primula*, which includes the Cowslip, the Primrose proper (*P. vulgaris*), the Polyanthus, a garden variety of this, the Oxlip (*P. elatior*), the Auricula (*P. Auricula*, from the Alps), &c. Many dwarf species of *Primula* and *Androsace* are "alpine plants," as is also *Soldanella*. *Glaux* and *Samolus* belong to salt-marshes; *Hottonia* to freshwater brooks, having feathery submerged leaves; the *Lysimachiæ* mostly grow in wet places. Many of the genera are represented in our native flora, while *Androsace*, *Dodecatheon*, and *Soldanella*, which are mostly alpine plants, are commonly cultivated.

(Myrsinaceæ are so closely related to Primulaceæ in the structure of the flowers that no absolute character of distinction can be drawn therefrom, since the imbedding of the ovules in the placenta, general here, occurs in several Primulaceous genera, for example in *Anagallis*. But the Myrsinaceæ are of shrubby or tree-like habit, and their fruit is fleshy. They belong chiefly to the islands of the Southern hemisphere; and some of them are cultivated in this country as evergreen shrubs requiring protection in winter. The seeds of some species of *Theophrasta* and *Myrsine* are nutritious; and the berries of some plants of the Order are edible, although others are said to be cathartic.)

(Ægiceraceæ include a genus of plants growing on sea-shores in the tropics, and rooting from the seed-vessels like Rhizophoraceæ, and considered to form a distinct Order by some writers. *Ægiceras* differs from Myrsinaceæ chiefly in having exalbuminous seeds, a follicular fruit, and transverse dehiscence of the anthers.)

## Order XCIV. SAPOTACEÆ.

*Class.* Petalanthæ, *Endl.* *All.* Rhamnales, *Lindl.* *Coh.* Sapotales, *Benth. et Hook.*

452. *Diagnosis.*—Trees or shrubs, mostly with a milky juice; leaves alternate, simple and entire (often rusty-downy beneath); flowers small, regular and perfect, usually in axillary clusters; calyx free and persistent; the fertile stamens commonly as many as the lobes of the short hypogynous corolla, and opposite to them, attached to the tube along with one or more rows of appendages and scales or sterile stamens; anthers extrorse; ovary 4–12-celled, with a single anatropous ovule in each cell; seeds large, usually albuminous.

### Illustrative Genera.

Chrysophyllum, *L.* | Isonandra, *Wight.* | Bassia, *Kön.*

**Affinities.**—Allied to Myrsinaceæ, but distinguished by the placentation, anatropal ovules, and other important characters,—also to the Ebenaceæ, which they resemble in habit; but they have a milky juice, and wood generally of a soft character; other differences also exist in the perfect flowers, such as erect ovules, simple styles, &c.

**Distribution.**—A considerable group. Chiefly tropical: Asia, Africa, and America.

**Qualities and Uses.**—The plants of this Order are valuable for succulent fruits, febrifuge bark, oleaginous secretions, and peculiar gum-resins in the milky juices. Of the fruits, the Sapodilla Plum (*Achras Sapota*), the Marmalade (*A. mammosa*), the Star-apple (*Chrysophyllum Cainito*), and the Surinam Medlar (*Mimusops Elengi*) are the most noted. The bark of various species of *Achras* has been used as a substitute for Cinchona. The fruits of *Bassia butyracea* and *B. longifolia* yield a butter-like oil, largely used in India; another species in Africa is said to yield the Shea or Galam butter mentioned by travellers. *Isonandra Gutta* is the tree from which Gutta Percha is obtained, by evaporating the milky juice.

## ORDER XCV. EBENACEÆ. THE EBONY ORDER.

*Class.* Petalanthæ, *Endl.* *All.* Gentianales, *Lindl.* *Coh.* Sapotales, *Benth. et Hook.*

453. *Diagnosis.*—Trees or shrubs with alternate entire leaves, without milky juice; flowers regular, polygamous, with the calyx free from the 3–12-celled ovary; the stamens twice or four times as many as the lobes of the corolla, often in pairs before them; anthers introrse; fruit a several-celled berry; ovules 1 or 2, suspended from the summit of each cell; seeds large, albuminous; radicle superior.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Royena, *L.* | Diospyros, *L.* |

**Affinities.**—The Ebenaceæ are distinguished from the Sapotaceæ by several important characters noted under that Order; on the other hand, they approach the Aquifoliaceæ in many points, but are separated by their strongly coherent floral envelopes, usually numerous stamens, and twin ovules, &c. To the Oleaceæ they are allied by the placentation and other points; but the alternate leaves, more numerous stamens, and commonly diclinous flowers afford very marked distinctions. The Styracaceæ are also very near to this Order, but frequently have an adherent calyx, petals less coherent, and a simple style with a capitate stigma.

**Distribution.**—A considerable group, the members of which are distributed mostly in tropical India, but a few are scattered elsewhere.

**Qualities and Uses.**—The principal property which has been noted in these plants is astringency; but they are better known and far more important on account of their hard and dark-coloured wood, the heart-wood of many species of *Diospyros* constituting Ebony; *D. Ebenus* yields it in Mauritius; *D. Melanoxylon* on the Coromandel coast; *D. Ebenaster* is the bastard Ebony of Ceylon; and *D. hirsuta* has a variegated wood called Calamander. Other species are also used. *D. virginiana*, a North-American species, bears the fruit called Persimmon or Date-plum, which is astringent when ripe, but is eaten after it has been affected by frost. *Diospyros Lotos* (Europe) and *D. Kaki* (China) have also edible fruit.

## ORDER XCVI. AQUIFOLIACEÆ OR ILICACEÆ.
### THE HOLLY ORDER.

*Class.* Frangulaceæ, *Endl.* *All.* Gentianales, *Lindl.* *Coh.* Olacinales, *Benth. et Hook.*

454. *Diagnosis.*—Trees or shrubs, with small axillary 4–6-merous flowers, sometimes diclinous by abortion; a minute corolla free from the 4–6-celled ovary and the 4–6-seeded berry; the stamens as many as the divisions of the almost or quite divided 4–6-petalous corolla, alternate with them, attached to the very base; ovary 2–6-celled; cells with 1 ovule; stigma almost sessile, lobed; fruit succulent, with 2–6-stones; seeds suspended, with copious fleshy albumen; radicle superior.

### ILLUSTRATIVE GENERA.

Ilex, *L.* | Prinos, *L.*

**Affinities.**—The affinities of Aquifoliaceæ to Ebenaceæ and Sapotaceæ have been noticed under those Orders. Some authors consider them related to Rhamnaceæ or Celastraceæ; but their monopetalous corolla, want of disk, straight embryo, and their relations to Ebenaceæ, as well as the difference in the ovary and seeds, remove them from the immediate neighbourhood of those Orders. On the other hand, they exhibit some approach to Loganiaceæ and Apocynaceæ.

**Distribution.**—A small Order, widely scattered, but sparingly. *Ilex Aquifolium,* the Holly, is the only European species.

**Qualities and Uses.**—The bark is ordinarily astringent and tonic, and that of the Common Holly is esteemed a febrifuge; its berries produce emetic and purgative action; its leaves, and still more those of *Ilex paraguayensis,* called Maté or Paraguay Tea, resemble Tea in property, as is the case also with *Prinos glabra,* a North-American shrub. Other species of *Ilex* are also used for this purpose in South America. The viscid substance called Bird-lime is made from the bark of the Holly; and its close white wood is valued by cabinet-makers.

(STYRACACEÆ are remarkable among the Orders here placed near it for the inconstancy of the character dependent on the adhesion of the calyx; Miers divides it into two, Symplocaceæ and Styracaceæ, separated by this mark, and by the æstivation of the corolla and other points. It is commonly regarded as related to Ebenaceæ among the Corollifloræ, and also to Aurantiaceæ and Ternstrœmiaceæ among the Thalamiflorals; while Lindley connects it with Celastraceæ through Sapotaceæ: others point out a resemblance to Philadelphaceæ.

**Distribution.**—Scattered sparingly in the warm regions of Asia and America.

**Qualities and Uses.**—Bitter and aromatic, sometimes containing a pungent resin. Gum Benzoin is obtained from *Styrax Benzoin* in the Malay archipelago; Storax from *St. officinale* in Syria; other species yield similar resins. *Symplocos* furnishes dyes or mordants; the leaves of *S. tinctoria* (Sweet-leaf, or Horse-sugar, North America) are sweet, and are eaten by cattle. *Halesia tetraptera*, another North-American plant, is called the Snowdrop-tree, on account of its numerous white bell-shaped blossoms.)

(OLACACEÆ are an Order of tropical trees and shrubs, apparently nearly related to Santalaceæ, but have distinct petals and a free ovary; they have the stamens opposite the petals. ICACINACEÆ, separated from the preceding by Miers, have the stamens alternate with the petals. In both the æstivation of the petals is valvate; while CYRILLACEÆ, a group of North-American shrubs, have imbricated petals. HUMIRIACEÆ are tropical American trees or shrubs with balsamic juice, and monadelphous stamens having an enlarged fleshy connective; they appear to be related to the Olacaceæ, while, on the other hand, they have affinities with the Styracaceæ and with the Aurantiaceæ. The systematic position of all these groups is at present unsettled, as is also that of CANELLACEÆ, a little group of plants connected with Clusiaceæ by some authors, by others with Olacaceæ and their allies.)

## ORDER XCVII. LOGANIACEÆ.

*Class.* Contortæ, *Endl.* *All.* Gentianales, *Lindl.* *Coh.* Gentianales, *Benth. et Hook.*

455. *Diagnosis.*—Shrubs or herbs with opposite leaves and interposed stipules sometimes reduced to an elevated line or a ridge; calyx 4–5-cleft; corolla hypogynous, monopetalous, regular, 4-, 5-, or 10-cleft, valvate or contorted or imbricated in æstivation: stamens inserted on the corolla; ovary superior, usually 2-celled; style divided above into as many lobes as the cells of the ovary; ovules numerous or solitary; fruit capsular, 2-celled, with the placentas finally detached, drupaceous, with 1- or 2-seeded stones, or baccate with the seeds immersed in pulp; seeds with a straight embryo in fleshy or cartilaginous albumen, sometimes winged, mostly peltate.

### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Usteria, *Willd.*<br>Spigelia, *L.* | Logania, *R. Br.*<br>Fagræa, *Thunb.* | Strychnos, *L.* |

**Affinities.**—This Order was formerly associated with Apocynaceæ and the neighbouring Orders; but, as remarked by Bentham, it consists, on the whole, of Rubiaceæ with a free ovary, at the same time approaching, by certain of its diverse forms, some of the genera of several of the Corollifloral Orders even more nearly than the general mass approach Rubiaceæ. To Apocynaceæ, which are very near in general structure, some genera, such as *Geniostoma*, which has contorted æstivation of the corolla, and *Mitrasacme*, where the carpels are partially distinct below and united above, approach very closely; *Mitrasacme* and *Mitreola* were formerly arranged as doubtful Gentianaceæ, and *Fagræa* and *Potalia* approach still more nearly, the former greatly resembling *Lisianthus* in character, while *Buddleia* and its allies have been referred to Scrophulariaceæ until lately, but are brought into this Order by Bentham, since they cannot be separated from *Logania*.

The main difference from Apocynaceæ lies in the stipules; but these are sometimes reduced to a mere line connecting the leaves: the peculiar stigma of that Order affords another means of separating them; and the Apocynaceæ often have hypogynous glands, which the Loganiaceæ have not. From Gentianaceæ the distinction lies generally in the stipules and the axile placentation; occasionally the succulent condition of the fruit is required as a decisive mark. From the Scrophulariaceæ the stipules, the regular corolla, the agreement of the number of stamens and lobes of the corolla, and quincuncial æstivation divide Loganiaceæ in most cases; and although that æstivation and the regular corolla occur sometimes in the former Order, there are then usually alternate leaves and no stipules. As observed by Bentham, this is hardly so much a Natural Order as a receptacle for anomalous forms of several really natural groups, Rubiaceæ, Apocynaceæ, Gentianaceæ, &c.

**Distribution.**—A rather large group, the species of which are chiefly tropical, but some are found in North America and Australia.

**Qualities and Uses.**—The plants belonging to this Order have mostly powerful poisonous properties, in particular the genus *Strychnos*. *S. Nux-vomica* bears the seeds known by its name, so noted for the presence of Strychnia. *S. toxifera* is said to furnish the active ingredient of the celebrated Woorali poison of Guiana. *S. cogens* is likewise used to poison arrows in Central America. *S. Tieuté* (the bark of the root) yields the Java poison called Upas Tieuté. Many seem to be free from strychnia as regards the bark; for that of *S. Pseudoquina* is used as a substitute for Cinchona in Brazil, that of *S. Nux-vomica* also, and the wood of *S. ligustrina*, called Lignum colubrinum. *S. potatorum*, an East-Indian species, is called the Clearing-nut; and it is said that, when its seeds are rubbed round in a vessel containing muddy water, it causes the impurities to settle. The seeds from the Philippines, known as St. Ignatius's Beans, have been described as the seeds of a plant called *Ignatia amara*; but Bentham has shown that this genus has no real existence, and that the seeds are probably those of an unknown *Strychnos*, perhaps *multiflora*, which grows on those islands. He states also that much uncertainty exists as to the identity of the many species described by authors, such as *S. cogens*, *ligustrina*, &c. The species of *Spigelia* are acro-narcotic; *S. marilandica*, the Carolina Pink-root, and *S. anthelmia* are used as vermifuges, but are somewhat dangerous, sometimes producing spasms and even convulsions. *Potalia amara* is bitter, acrid, and emetic.

## ORDER XCVIII. GENTIANACEÆ. THE GENTIAN ORDER.

*Class.* Contortæ, *Endl.* *All.* Gentianales, *Lindl.* *Coh.* Gentianales, *Benth. et Hook.*

456. *Diagnosis.*—Smooth herbs, with a colourless bitter juice, opposite and sessile leaves, mostly simple, entire, and strongly ribbed, without stipules; flowers regular, with a persistent calyx, with stamens as many as the lobes of the usually withering-persistent corolla, and which are convolute (rarely imbricated, and sometimes

valvate) in the bud; ovary 1-celled, with two parietal placentas, projecting more or less toward the centre; the fruit mostly a 2-valved, septicidal, many-seeded capsule, sometimes with a fleshy pericarp; seeds small; embryo minute in the axis of fleshy albumen.

### ILLUSTRATIVE GENERA.

Gentiana, *L.*
Agathotes, *Don.*
Erythræa, *Ren.*
Chlora, *L.*
Menyanthes, *L.*
Villarsia, *Vent.*

**Affinities.**—This Order stands very near Apocynaceæ, from which it differs in its placentation and completely coherent carpels, habit, want of milky juice, and other points. The parietal placentas distinguish it from the Scrophulariaceæ and allied Orders which sometimes show an approach to the regular structure of Gentianaceæ. Gesneraceæ differ in their irregular flowers, axile embryo, and other characters. An affinity exists to Orobanchaceæ, especially through *Obolaria*, a N.-American plant formerly referred to that Order, *Voyra*, a parasitic leafless genus, and some allied forms lately discovered in South America, while *Crawfurdia*, a twining genus, seems to connect the Gentianaceæ with Convolvulaceæ.

**Distribution.**—A large Order, generally diffused—the large genus *Gentiana* especially inhabiting the mountains of temperate and hot climates, but not in polar regions.

**Qualities and Uses.**—Bitter, tonic properties are general; a few are emetic or narcotic, especially when fresh. Among the bitter kinds medicinally employed are the Gentians, *G. lutea* (officinal), *punctata, purpurea, pannonica*, all European, *G. Catesbæi* (U.S), *G. Kurroo* (Himalaya), *Frasera Walteri* (U.S), *Agathotes Chirayita*, a native of the Himalayas. *Erythræa Centaurium, Menyanthes trifoliata, Chlora perfoliata, Gentiana campestris* and *Amarella*, all British herbs, have been used in the same way. The plants of this Order mostly have beautiful flowers, brilliant blue predominating, but red, white, and purple, and more rarely yellow occurring. The Gentianella of our gardens is *G. acaulis*; and the smaller Gentians are among the most beautiful of alpine plants. *Villarsia nymphæoides* is an elegant water-plant occurring in Britain. *Limnanthemum*, an exotic genus, is also aquatic.

## ORDER XCIX. APOCYNACEÆ. DOG-BANES.

*Class.* Contortæ, *Endl.* *All.* Gentianales, *Lindl.* *Coh.* Gentianales, *Benth. et Hook.*

457. *Diagnosis.*—Plants with milky acrid juice, entire (mostly opposite) leaves, without stipules; flowers regular, 5-merous and 5-androus; the 5 lobes of the corolla convolute and twisted in the bud; the filaments distinct, inserted on the corolla, and the pollen granular; ovary 2- or more rarely 1-celled, composed of 2 carpels more or less coherent in the ovarian and stylar region and quite blended in the drum-shaped or dumbbell-shaped stigma; ovules nu-

merous ; fruit 1 or 2 follicles, a capsule, drupe, or berry ; seeds mostly with fleshy or cartilaginous albumen.

ILLUSTRATIVE GENERA.

Allamanda, *L.*
Hancornia, *Gomez.*
Carissa, *L.*
Tanghinia, *Thouars.*
Tabernæmontana, *Plum.*
Vinca, *L.*
Wrightia, *R. Br.*
Nerium, *L.*
Apocynum, *Tournef.*
Dipladenia, *DC.*

**Affinities.**—Related closely to some Loganiaceæ and to Gentianaceæ, as noticed under those Orders—also to Asclepiadaceæ, from which they are chiefly distinguished by the freedom of the stamens from the stigma and by the coherent pollen. The thickened stigma, however, and appendaged anthers found here indicate a close relationship. *Alyxia* has ruminate albumen.

**Distribution.**—A large group, the species of which are chiefly tropical, a few scattered in temperate climates. *Vinca* occurs in Britain.

**Qualities and Uses.**—Often violent poisons, acting as drastic purgatives and emetics, sometimes with a narcotic influence. Not a few, however, have delicious edible fruits; and the bark of some is tonic and febrifuge. The milky juice contains Caoutchouc, in some cases sufficient to become commercially valuable. The poisonous principles appear to occur chiefly in the seeds and in the milky juice. The seeds of *Tanghinia venenifera*, the Madagascar Poison-nut, are very deadly, as are also the seeds of *Cerbera, Thevetia, Cameraria latifolia* (the Bastard Manchineel), the stem, root, leaves, and flowers of *Nerium* (the Oleander), *Echites, Plumiera,* &c. Where somewhat milder, as in *Apocynum* and *Allamanda*, the plants are occasionally available medicinally, but only in small doses. *Wrightia antidysenterica*, some species of *Carissa, Hancornia pubescens*, and others are simply bitter and febrifuge, like Gentians. The succulent fruits of *Hancornia speciosa* (Brazil), *Carissa Carandas* and *edulis* (East Indies), *Roupellia grata* (Sierra Leone), are not only harmless, but very delicious. Caoutchouc is obtained from *Urceola elastica, Willughbeia edulis* (East Indies), *Vahea gummifera* (Madagascar), *Collophora utilis* and *Cameraria latifolia* (South America). The milky juice of *Tabernæmontana utilis*, the Cow-tree of Demerara, is innocuous and nutritious. *Wrightia tinctoria* furnishes a kind of indigo; and the wood of species of *Wrightia* (East Indies), *Aspidosperma* (Guiana), &c. is valuable as timber. This Order furnishes some of our most beautiful stove-plants—*Echites, Allamanda, Dipladenia, Nerium, Plumiera,* &c. forming striking ornaments in every extensive horticultural collection.

## ORDER C. ASCLEPIADACEÆ.

*Class.* Contortæ, *Endl.* *All.* Solanales, *Lindl.* *Coh.* Gentianales, *Benth. et Hook.*

458. *Diagnosis.*—Shrubs or herbs, often twining, with milky juice, opposite or whorled (rarely scattered) entire leaves without stipules ; flower regular, 5-merous, 5-androus, the lobes of the corolla

mostly valvate; carpels 2, distinct, but adherent below; stigmas coherent into a 5-angled fleshy head, to which the anthers are adherent (fig. 393); pollen coherent into wax-like or granular masses; ovaries with numerous ovules on the sutures; fruit a pair of follicles, or by abortion 1; seeds mostly with a crown of hairs at the hilum, with thin albumen.

ILLUSTRATIVE GENERA.

Hemidesmus, *R. Br.*
Periploca, *L.*
Vincetoxicum, *Mœnch.*
Calotropis, *R. Br.*
Cynanchum, *L.*
Asclepias, *L.*
Hoya, *R. Br.*
Stapelia, *L.*

Fig. 393.

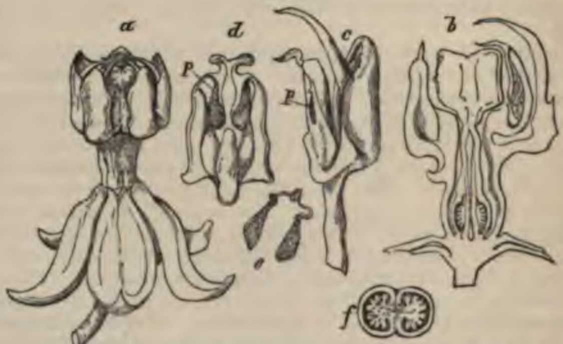


Fig. 393. *a*, Flower of *Asclepias purpurascens*; *b*, a vertical section, with the petals removed; *c*, side view of a stamen; *d*, inside view of an anther (*p*, pollen-sac); *e*, two pollen-masses; *f*, cross section of the ovary.

**Affinities.**—The curious organization of the stigma and pollen is the great distinguishing feature of this Order, which in other respects is closely allied to Apocynaceæ. When the pollen is mature, it escapes in "pollen-masses" from the anthers (fig. 393, *e*), and adheres to gelatinous processes developed on the sides of the stigma, which retain it, so that it can push its pollen-tubes into the lateral and inferior stigmatic surfaces; after fertilization, the stigma with the adherent anthers and filaments separate from the style and leave a pair of distinct carpels, which ripen (one or both) into free follicles.

**Distribution.**—A large Order, mostly tropical, in Asia, Africa, and America; one or two species occur in Europe, and a few in North America.

**Qualities and Uses.**—Generally resembling the Apocynaceæ; but the active properties are not so much developed, and the succulent fruits do not appear here. Species of *Asclepias, Cynanchum, Calotropis* (Mudar), and *Periploca* are more or less emetic or purgative; the leaves of *Solenostemma Arghel* and *Gomphocarpus fruticosus* are frequent adulterations in Alexandrian Senna, and are said to cause griping. The roots of *Hemidesmus indicus* are used as a substitute for Sarsaparilla. The milky juice of

*Cynanchum ovalifolium* yields Caoutchouc at Penang. *Marsdenia tenacissima* and *Orthanthera viminea*, East-Indian plants, afford a very tenacious fibre; *Marsdenia tinctoria* a kind of Indigo. The *Stapeliæ* and *Ceropegiæ* are remarkable for their succulent habit; some of them form curious tubers, as *Brachystelma*. *Hoya* partakes of the succulent habit, but has wax-like leaves and blossoms, sometimes very handsome. *Dischidia* is remarkable for its pitcher-leaves (§101). *Gymnema lactifera* is the Cow-plant of Ceylon, which yields a milky juice, harmless and nutritious, and which is used by the natives as food.

(HYDROPHYLLACEÆ form a small Order, allied in some respects to Boraginaceæ, but differing in their one-celled many-seeded ovary with parietal placentation, which also separates them from Polemoniaceæ, with which they have many points of agreement. They are chiefly natives of the north and extreme south of America. Their properties are unimportant; but species of some of the genera, as *Nemophila*, *Eutoca*, &c., are interesting and showy garden plants, grown with us as tender annuals. Hydroleads are sometimes separated from this Order by reason of their distinct styles and anatropous ovules.)

(DIAPENSIACEÆ consist of two genera, *Diapensia* and *Pyxidanthera*, each having one species. They are connected with Convolvulaceæ by some authors, but appear to stand between Hydrophyllaceæ and Polemoniaceæ, having a 3-celled ovary like the latter, and a filiform embryo with very short cotyledons, approaching that of the former. They are very closely allied to Ericaceæ, but the anthers do not open by pores.)

## ORDER CI. POLEMONIACEÆ. THE PHLOX ORDER.

*Class.* Tubifloræ, *Endl.* *All.* Solanales, *Lindl.* *Coh.* Convolvulales ?, *Benth. et Hook.*

459. *Diagnosis.*—Herbs with alternate or opposite leaves, regular 5-merous and 5-androus flowers, the lobes of the corolla mostly convolute (sometimes imbricated) in æstivation; ovary 3-celled, style 3-lobed; the capsule 3-celled, 3-valved, loculicidal, few- or many-seeded; valves usually breaking away from a triangular central columella; seeds albuminous; embryo straight; cotyledons elliptical, foliaceous.

### ILLUSTRATIVE GENERA.

Phlox, *L.*
Collomia, *Nutt.*
Leptosiphon, *Benth.*
Polemonium, *Tournef.*
Cantua, *Juss.*
Cobæa, *Cav.*

**Affinities, &c.**—One of the smaller Orders; it is remarkable for its 3-celled ovary. It is nearly related to Convolvulaceæ, *Cobæa* agreeing even in the climbing habit; the ovary equally distinguishes it from these, the Hydrophyllaceæ, and the Gentianaceæ, to all of which it has close affinity. From Diapensiaceæ it differs in the regular calyx and insertion of the stamens, as well as in the embryo. The seeds are remarkable in many cases for hairs upon the testa containing a spiral fibre; in *Collomia* these expand elastically when wetted; in *Cobœa* they are short, broad, and firm. The Polemoniaceæ occur most abundantly in the temperate regions of North and South America. *Polemonium cæruleum*, Greek Valerian or Jacob's Ladder, grows in the north of England, and is common in gardens. The other genera furnish some of the favourite tender perennial and annual herbaceous plants of our gardens. They have no important properties.

## ORDER CII. CONVOLVULACEÆ. THE BINDWEED ORDER.

*Class*. Tubifloræ, *Endl.* *All*. Solanales, *Lindl.* *Coh*. Convolvulales, *Benth. et Hook.*

460. *Diagnosis*.—Chiefly twining or trailing herbs, sometimes leafless and parasitic, or shrubby and erect, often with some milky juice; with alternate leaves (or scales); flowers regular, 5-androus; calyx of 5 imbricated sepals, the 5-plaited or 5-lobed corolla convolute or twisted in the bud; ovary 2-celled (rarely 3-celled), or with 2 separate pistils, with 2 erect ovules in each cell, the cell sometimes doubled by a false partition between the seeds, thus falsely 4-celled; embryo large, curved or coiled in mucilaginous albumen, with foliaceous cotyledons, or (*Cuscuteæ*) filiform and coiled with the cotyledons scarcely perceptible; radicle inferior.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Convolvulus, *L.* | Ipomœa, *L.* |
| Exogonium, *Chois.* | Cuscuta, *Tournef.* |

**Affinities.**—This Order approaches the regular monopetalous Boraginaceæ, Polemoniaceæ, and allied Orders; the structure of the ovary separates it from the first, the curved embryo and the fruits from the second. Cordias also differ in their exalbuminous seeds and superior radicle. Some of the Convolvulaceæ are of shrubby habit, and depart widely from the appearance with which we are most familiar. *Cuscuta* is sometimes made the type of a distinct Order; but the parasitical habit is not a sufficient character.

**Distribution.**—A large Order, of which a few species occur in temperate climates, but the majority belong to the tropics.

**Qualities and Uses.**—A purgative property generally characterizes these plants, among which are several yielding important medicinal substances. True Jalap is the root of *Exogonium Purga*, Scammony of *Convolvulus Scammonia*; *Pharbitis cathartica* and *Ipomœa tuberosa* yield a similar substance. The white hedge-Convolvulus, *Calystegia sepium*, has a similar action, as also various *IpomϾ* and *Convolvuli*, the active matter being a kind of resin existing in the milky juice. The seeds of *Pharbitis Nil* and *P. cærulea* are also used as purgatives. On the other hand, *Batatas edulis* forms a large fleshy tuber, which is widely cultivated and eaten under the name of the Sweet Potato, and *Ipomœa macrorhiza* has edible farinaceous roots. The twining and trailing plants of this Order are mostly remarkable for the beauty of their flowers, and many of them are cultivated; the garden Major Convolvulus is *Pharbitis purpurea*, the blue Minor Convolvulus is *Convolvulus tricolor*. *Convolvulus arvensis*, Bindweed, grows everywhere, on the ground, rooting at the nodes; *C. Soldanella* grows in like manner on the sea-shore; *Calystegia sepium*, the White Convolvulus, is one of our most beautiful and at the same time commonest hedge-plants.—The *Cuscutæ* are remarkable for their leafless parasitic habit; they germinate in the ground, and then coil themselves round the stems of plants and send roots in through their rind, by which they are then entirely nourished. They have wire-like stems with minute scales at the nodes, and tufts of small Convolvulaceous flowers. They are great pests in clover- and flax-fields, destroying the plants they infest.

## ORDER CIII. SOLANACEÆ. NIGHTSHADES.

*Class.* Tubifloræ, *Endl.* *All.* Solanales, *Lindl.* *Coh.* Convolvulales, *Benth. et Hook.*

461. *Diagnosis.*—Herbs, rarely shrubs, with colourless juice and alternate leaves; flowers regular, or slightly irregular, often extra-axillary, 5-merous and 5-androus, on bractless pedicels; corolla hypogynous, plaited-imbricate, plaited-convolute, or involutive-valvate in æstivation; stamens epipetalous; ovary 2-celled, cells antero-posterior; fruit a 2-celled (rarely 3–5-celled) many-seeded capsule or a succulent berry. Seed albuminous; embryo curved.

### *Character.*

*Calyx* free, or rarely 4- or 6-cleft, persistent, or the upper part separating by transverse dehiscence, mostly growing somewhat during the ripening of the fruit (accrescent).

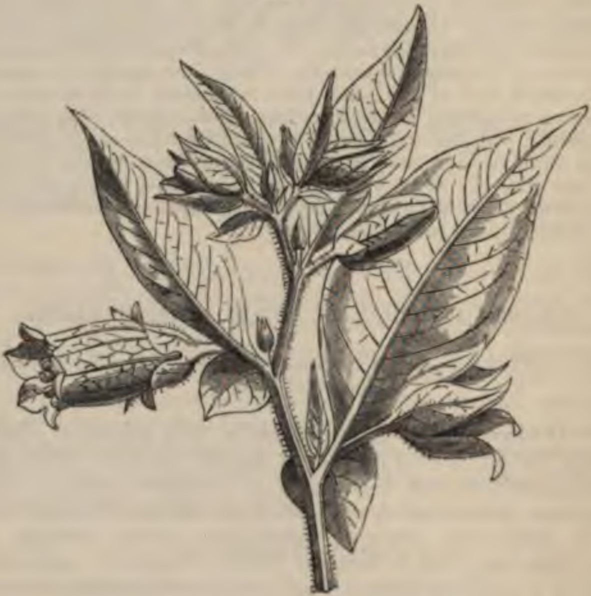
*Corolla* monopetalous, 5- or rarely 4- or 6-parted or toothed, rotate, campanulate, funnel- or salver-shaped, sometimes obliquely irregular, plaited-imbricate, plaited-convolute, or involutive-valvate in the bud.

*Stamens* attached to the tube of the corolla, equal in number to its lobes and alternate with them; *filaments* sometimes rather unequal; *anthers* 2-celled, with the cells sometimes connate above, dehiscing longitudinally or by terminal pores.

*Ovary* usually 2-celled, the carpels antero-posterior; placentas axile, sometimes enlarged into spurious dissepiments, rendering the ovary 4-celled; ovary rarely 3–5-celled by increased number of carpels; *ovules* numerous; *style* simple; *stigma* simple or lobed.

*Fruit* capsular, with septicidal or transverse dehiscence (fig. 291), or a succulent or dryish indehiscent berry (fig. 295); *seeds* numerous, the embryo mostly slender and curved, sometimes straight, with foliaceous cotyledons in fleshy albumen.

Fig. 394.



*Atropa Belladonna.*

Fig. 395.

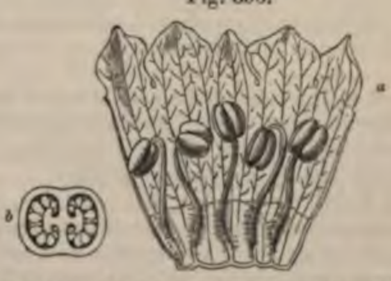


Fig. 395. *a*, Corolla of *Atropa Belladonna*, showing the attachment of the stamens; *b*, cross section of the ovary.

### ILLUSTRATIVE GENERA.

*Petunia, *Juss.*
*Nicotiana, *Tournef.*
*Datura, *L.*
*Hyoscyamus, *Tournef.*
Physalis, *L.*
Capsicum, *Tournef.*
Solanum, *L.*
*Atropa, *L.*
*Mandragora, *Tournef.*

**Affinities.**—A considerable range of variation in the condition of most of the organs upon which a character is founded renders it difficult to circumscribe this Order strictly; in fact it passes by almost insensible gradations into the Scrophulariaceæ. Generally speaking, the Solanaceæ are distinguished by the plaited æstivation of the corolla, equality of the number of stamens with the lobes of the corolla, and a curved embryo from the Scrophulariaceæ, which have imbricated æstivation, stamens fewer than the lobes of the corolla, and a straight embryo; but none of these characters are constant in the former Order; yet the nearly regular corolla and five perfect stamens will in almost all cases distinguish the Solanaceæ. Miers has lately proposed, in extension of a suggestion of R. Brown, to establish a new Order, Atropaceæ, to include the aberrant forms of Solanaceæ and Scrophulariaceæ, and leave these better defined—the brief diagnoses of these Orders being:—

1. SOLANACEÆ. Stamens equal in number to the lobes of the corolla (or petals), whose æstivation is valvate or induplicate-valvate.
2. ATROPACEÆ. Stamens equal in number to the lobes of the corolla (or petals), one sometimes sterile; æstivation of the corolla imbricated, or some modification of imbricated.
3. SCROPHULARIACEÆ. Stamens less in number than the lobes of the corolla (or petals), 4 or 2; æstivation of the corolla imbricated.

The removal of the *Buddleieæ* to Loganiaceæ, as proposed by Bentham, is favourable to this arrangement, as it removes the 4-androus genera with regular 4-lobed corollas, which would render the above diagnosis of Scrophulariaceæ faulty. In the list of genera given above, the Solanaceous genera of Miers are left open, and those are marked with an asterisk which are referred to his Atropaceæ, together with a number which will be found similarly distinguished under Scrophulariaceæ.

The Solanaceæ, as a whole, have, however, closer relations with some of the regular monopetalous Orders, particularly with Hydrophyllaceæ and Convolvulaceæ; they are connected with Boraginaceæ by *Grabowskia*, a Brazilian genus, formerly regarded as a *Lycium*, which has the habit of the latter with the ovary of Boraginaceæ: it is nearly related to *Nolana*. According to Lindley, *Cestrum* connects the Solanaceæ with the Oleaceæ, through *Syringa*; but although it has a straight embryo with foliaceous cotyledons, the radicle is inferior, not superior, and the resemblance appears to exist chiefly in habit. Polemoniaceæ differ in their 3-celled ovary and straight embryo.

**Distribution.**—A very large Order, the members of which are generally distributed, but most abundantly in the tropics.

**Qualities and Uses.**—The genera referable to Atropaceæ, as indicated above, are mostly characterized by powerful narcotic poisonous properties. The Solanaceæ are apparently less powerful in all cases, and certain kinds furnish wholesome and some most important articles of food; but many of them possess decided narcotic properties. Some are distinguished by an acrid or pungent quality; some have diuretic action; and others are accounted tonics. Among the poisonous kinds the most important are:—the *Atropa Belladonna* (Deadly Nightshade, which has the curious property of relaxing the iris, and thus causing dilatation of the pupil); *Datura Stramonium* (the Thorn-apple), and other species of *Datura*, such as *D. Metel*, *Tatula*, *ferox*, &c.; *Hyoscyamus niger* (Henbane) and other species; *Nicotiana Tabacum*, *persica*, and *rustica* (the American, Persian, and Syrian Tobacco-plants); *Mandragora officinalis* (the Mandrake). *Acocanthera venenata*, a Cape shrub, is said to be more deadly even than any of them. The foliage of some species of *Solanum* is said to have active properties of the same kind, especially *S. nigrum* (Black Nightshade), *S. Dulcamara* (Bitter-sweet or Woody Nightshade), and even the leaves and stems of *S. tuberosum* (the common Potato) and *Physalis somnifera*. *Solanum Pseudo-quina* is employed in Brazil as a substitute for Cinchona. Some species of *Cestrum*, as *laurifolia* and *Pseudo-quina*, are said to have similar properties. Other *Cestra*, as *C. euanthes*, *lævigatum*, &c., many species of *Physalis*, *Solanum*, &c., are accounted diuretic.

The species of *Capsicum* are remarkable for the pungent quality of the fruits, the common Capsicum being the produce of *C. annuum*, and Cayenne pepper consisting of the powdered seeds of various species, such as *C. frutescens*.

While some of the plants are such active poisons in all parts, others are only partially or not at all so. The berries as well as the foliage of *Atropa*, for example, and the seeds and capsules as well as the foliage of *Hyoscyamus*, are very deadly; but the succulent fruits of many species of *Solanum* are wholesome, as the Egg-Apple or Aubergine (*S. Melongena*), those of *S. laciniatum*, eaten in Australia under the name of Kangaroo Apples, &c., and, it is said (but this wants confirmation) those of the *S. nigrum*, *Dulcamara*, and others. *Lycopersicum esculentum*, the Tomato, is another example. Still more striking appears the instance of the Potato, at first sight; but it must be remembered that the edible tuber is an artificial product, and consists chiefly of cellular tissue and starch developed under circumstances that *oppose* the formation of the noxious secretion; and what is present may be dissipated by heat. It is said that the poisonous element in Solanaceous fruits exists in a pulpy covering of the seeds, not in the pericarp. It is desirable that this point should be ascertained.

(CORDIACEÆ constitute an Order, chiefly consisting of tropical plants, sometimes combined with the Boraginaceæ, from which they differ in the twisted æstivation of the corolla and the plaited cotyledons. From Convolvulaceæ they differ in their superior radicle and the absence of albumen. The Order is remarkable for the plaited cotyledons of the embryo. The fruits of *Cordia Myxa* and *latifolia* are called Sebestens or Sebesten plums, and, with those of other species, are edible.)

(NOLANACEÆ are a small group of South-American plants referred by some authors to Convolvulaceæ, by others to Boraginaceæ, sometimes erected into a distinct Order on account of the valvate calyx, plaited regular corolla, the ovary of 5–20 carpels, either distinct, or when numerous combined into several sets, seated on a fleshy disk, with a single style and stigma; the embryo curved, in little albumen. The chief distinction from

Boraginaceæ lies in the 5-merous ovary and the absence of the scroll-like inflorescence; they may be regarded as aberrant forms of that Order. Some species of *Nolana* are cultivated in gardens for their showy flowers, somewhat resembling blue *Convolvuli*. Their properties are unknown. Genera: *Nolana*, L.; *Alona*, Lindl.)

## ORDER CIV. BORAGINACEÆ. THE BUGLOSS ORDER.

*Class.* Nuculiferæ, *Endl.* *All.* Echiales, *Lindl.* *Coh.* Verbenales, *Benth. et Hook.*

462. *Diagnosis.*—Chiefly roughly hairy herbs (not aromatic), with alternate entire leaves, a scorpioid inflorescence, and symmetrical flowers with a 5-parted calyx, an hypogynous, regular (rarely slightly irregular) 5-lobed corolla, 5 stamens springing from the corolla-tube; ovary deeply 4-lobed, the lobes surrounding the base of the single gynobasic style, and forming when ripe 4 indehiscent 1-seeded achenes in the bottom of the persistent calyx; stigma simple or bifid; seeds separable from the pericarp, exalbuminous; radicle superior.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Echium, *L.* | Symphytum, *L.* | Lithospermum, *L.* |
| Borago, *Tournef.* | Anchusa, *L.* | Myosotis, *L.* |

**Affinities.**—The 4-lobed ovary and fruit of this Order agree exactly with those of the Labiatæ, in which the irregular corolla, didynamous stamens, opposite leaves, and square stems differ widely. This character of the ovary does not occur in any other regular 5-androus monopetalous Order. The Nolanaceæ and Ehretiaceæ depart from the general type of this Order. Ehretiaceæ seem to bear the same relation to the proper Boraginaceæ as the Verbenaceæ to Labiatæ, having confluent carpels, terminal styles, and a shrubby or arborescent habit. The corolla mostly presents a coronet of scales in the throat, which some incline to regard as abortive stamens.

**Distribution.**—A large Order, the species of which are mostly natives of temperate climates in the northern hemisphere.

**Qualities and Uses.**—The plants of this Order, remarkable for their rough foliage, have a reputation as mucilaginous and cooling herbs. Their chief importance lies in the dye furnished by the roots of *Anchusa tinctoria* (Alkanet) and various species of *Echium*, *Onosma*, &c., and the beauty of their flowers, whence the genera above cited include many common garden plants. The Forget-me-not is a native species of the genus *Myosotis*. Many Boraginaceæ occur wild with us.

(EHRETIACEÆ consist of a group of plants separated from Boraginaceæ by some authors on account of the coherence of the carpels and the terminal style (which is gynobasic (§ 228) in true Boraginaceæ) and a drupaceous fruit. Some genera have albumen, others not. They seem to be as distinct here as Verbenaceæ from the Labiatæ; but the agreement is very close at some points in both cases. They are also nearly related to the Cordiaceæ; but the latter have twisted æstivation and plaited cotyledons. Most of them are tropical trees or shrubs. None are of much importance: the drupes of some *Ehretiæ* are eaten; the Heliotrope (*Heliotropium peruvianum*) is universally known for its delicious odour. Genera: *Ehretia*, L.; *Tournefortia*, R. Br.; *Heliotropium*, L., &c.)

## ORDER CV. LABIATÆ.

*Class.* Nuculiferæ, *Endl.* *All.* Echiales, *Lindl.* *Coh.* Verbenales, *Benth. et Hook.*

463. *Diagnosis.*—Chiefly herbs, with square stems and opposite aromatic leaves; flowers with a more or less 2-lipped, hypogynous corolla, didynamous or diandrous stamens; ovary deeply 4-lobed, the lobes surrounding the base of the single gynobasic style, and forming, when ripe, 4 indehiscent 1-seeded achenes in the bottom of the persistent calyx; stigma bifid; seeds erect, with little or no albumen.

*Character.*

*Calyx* inferior, persistent, tubular, 5-merous, with the odd sepal posterior; the limb regularly 5- or 10-toothed, or irregular and bilabiate (fig. 396), 3- to 10-toothed.

*Corolla* hypogynous, monopetalous, bilabiate; the upper lip entire or divided, arched or almost suppressed; the lower lip usually larger and 3-lobed (fig. 397).

Fig. 396.

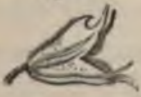


Fig. 397.

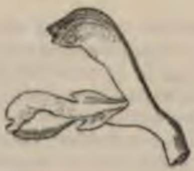


Fig. 398.

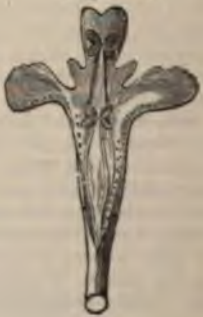


Fig. 396. Calyx of *Salvia*.
Fig. 397. Corolla of *Salvia*.
Fig. 398. Corolla of *Glechoma* opened, showing the didynamous stamens.

*Stamens* springing from the corolla, 4, didynamous (fig. 398), or sometimes 2; *anther* 2-celled or apparently 1-celled from the apposition of the cells at the apex, or with the filament or connective bifurcate and bearing either 2 single cells or 1 perfect cell and a sterile process.

*Ovary* deeply 4-lobed, on a fleshy disk, 4-celled, each cell with 1 erect ovule; *style* simple, arising from the bottom of the carpels; *stigma* forked.

*Fruit* composed of 4, or, by abortion, 3, 2, or 1, dry, separable, 1-seeded portions, surrounded by the persistent calyx; *seeds* with little albumen; cotyledons flat.

### ILLUSTRATIVE GENERA.

Lavandula, *L.*
Mentha, *L.*
Salvia, *L.*
Rosmarinus, *L.*
Origanum, *L.*
Thymus, *L.*
Hyssopus, *L.*
Prunella, *L.*
Lamium, *L.*
Stachys, *Benth.*
Marrubium, *L.*
Ballota, *L.*
Phlomis, *L.*
Teucrium, *L.*
Ajuga, *L.*

**Affinities.**—As regards the structure of its ovary, this Order agrees exactly with Boraginaceæ, from which, however, almost all its other characters distinguish it. Among the didynamous unsymmetrical monopetalous Orders, no other group approaches this structure but Verbenaceæ, which are distinguished by the greater degree of coherence of the carpels and the terminal style, as the Ehretiaceæ are from Boraginaceæ; but the separation of these Orders is sometimes difficult. Disregarding the ovary, the character of the corolla and stamens connects Labiatæ with Scrophulariaceæ and its allies, especially when they have opposite leaves and square stems.

The morphology of the corolla and stamens is very interesting in this Order, as it is in the Scrophulariaceæ; the didynamous structure arises from the want of the posterior stamen, and in the diandrous genera it is the anterior pair that remains. The foliage of the majority of plants in this Order is studded with microscopic glandular hairs, containing the essential oils to which they owe their remarkable fragrance. Various species of *Salvia* have hairs upon the testa of the seed, containing a spiral fibre, somewhat as in Polemoniaceæ.

**Distribution.**—A very large Order, the species of which are principally natives of temperate climates; but the more fragrant kinds occur most abundantly in the warm temperate and drier regions.

**Qualities and Uses.**—The most striking qualities of this Order depend upon the presence of aromatic or fragrant essential oils, which render some of them valuable stimulants and antispasmodics, others favourite flavouring herbs for culinary purposes, others important ingredients in perfumes, &c. Some are also regarded as tonics. The fleshy subterraneous rhizomes of *Stachys palustris* are sometimes cultivated as a table vegetable; and the tubers of an *Ocimum* are said to be eaten in Madagascar.

Of the carminative aromatics, the Mints, Spearmint (*Mentha viridis*), Peppermint (*M. Piperita*), Penny-royal (*M. Pulegium*) are among the best-known. Other species of *Mentha* have similar properties; *Hedeoma pulegioides*, the Penny-royal of the United States; Lavender, *Lavendula vera*; together with the inferior French Lavender, *L. Spica*, the oil of which, however, is chiefly used in the arts (oil of Spike), and others: many allied species are used in different countries in the same way. The essential oils of some kinds commonly used as flavouring herbs are also used in veterinary medicine. Among the best-known of these, besides Mint, are Thyme (*Thymus Serpyllum* and other species), Marjoram (*Origanum*, various species), Basil (*Ocimum*, sp.), Savory (*Satureia*, sp.), Sage (*Salvia officinalis* and *grandiflora*), &c. As perfumes, Lavender, Patchouli (*Pogostemon Patchouli*), *Mentha citrata*, Rosemary (*Rosmarinus officinalis*), and others are largely used. Horehound (*Marrubium vulgare*) is an old-fashioned remedy for coughs; Ground-Ivy (*Nepeta Glechoma*), Balm (*Melissa officinalis*), and others are used by the country-people for the same complaints. *Monarda fistulosa* (a North-American shrub) and *Origanum Dictamnus* (or Dittany of Crete) are reputed febrifuges. *Stachys Betonica* has been regarded as a sternutatory, but perhaps acts mechanically: its root is said to be purgative and emetic; but this seems unlikely to be true.

Many plants of this Order decorate our gardens, and many species are wild in Britain.

## ORDER CVI. VERBENACEÆ. THE VERVAIN ORDER.

*Class.* Nuculiferæ, *Endl.* *All.* Echiales, *Lindl.* *Coh.* Verbenales, *Benth. et Hook.*

464. *Diagnosis.*—Herbs or shrubs with opposite or alternate leaves; flowers with an hypogynous more or less 2-lipped or irregular corolla and didynamous stamens; style terminal; the 2–4-celled fruit dry or drupaceous, usually splitting when ripe into as many 1-seeded, indehiscent nucules; seeds erect or pendulous, with little or no albumen.

### ILLUSTRATIVE GENERA.

Suborder 1. VERBENEÆ. *Ovules ascending; seed exalbuminous; leaves opposite.*

- Verbena, *L.*
- Lantana, *L.*
- Tectona, *L.*
- Clerodendron, *L.*
- Vitex, *L.*

Suborder 2. MYOPOREÆ. *Ovules pendulous; seed albuminous; leaves alternate.*

- Myoporum, *Bks. & Sol.*
- Avicennia, *L.*

**Affinities.**—Principally distinguished from Labiatæ by the terminal style and more coherent carpels. The *Myoporeæ* can hardly be separated from the *Verbeneæ*; and perhaps Selaginaceæ should be appended as an aberrant form. The structure of the fruit separates this Order from Scrophulariaceæ and its allies.

**Distribution.**—A large Order, chiefly tropical; the *Verbeneæ* common in temperate South America, and a few scattered in all regions. The *Avicenniæ* grow, like Mangroves, in tropical salt marshes.

**Qualities and Uses.**—Those of the *Verbeneæ* are much the same as in Labiatæ: *Aloysia citriodora*, the cultivated "Lemon-plant," or "Verbena," is an instance of fragrant properties; many species of *Lantana* are fragrant or fœtid; some are used as substitutes for Tea. *Vitex Agnus-castus*, *V. Negundo*, and others have acrid fruits. *Tectona grandis* is the East-Indian Teak-tree, celebrated for its hard heavy wood (African Teak is from a Euphorbiaceous tree). The bark of *Avicennia tomentosa*, the White Mangrove of Brazil, is used for tanning. Clerodendrons are handsome stove-shrubs. The brilliant Verbenas of our gardens are mostly varieties of *Verbena chamædrifolia* and allied species.

(SELAGINACEÆ are a small group differing from Verbenaceæ principally in having 1-celled anthers; in *Globularia* the carpels are reduced to one. Hence there appears a connexion between them and Salvadoraceæ, which approach Verbenaceæ and *Ehretieæ* among the Boraginaceæ in other points. Some of the plants are European; most of them belong to the Cape. *Globulariæ* have purgative and emetic properties. Genera: *Selago*, L.; *Globularia*, L.)

## ORDER CVII. ACANTHACEÆ.

*Class.* Personatæ, *Endl.* *All.* Bignoniales, *Lindl.* *Coh.* Personales, *Benth. et Hook.*

465. *Diagnosis.*—Herbs or shrubs with opposite simple leaves; flowers irregular, bracteated, with an imbricated hypogynous more or less 2-lipped corolla, didynamous or diandrous stamens attached to the tube of the corolla; fruit a 2-celled, 4–12-seeded capsule; seeds anatropous, exalbuminous, usually flat, supported by hooked or cup-shaped projections of the placentas; radicle inferior.

### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Thunbergia, *L.* | Barleria, *L.* | Adhatoda, *Nees.* |
| Ruellia, *L.* | Acanthus, *L.* | Justicia, *L.* |

**Affinities.**—This Order is closely related to Scrophulariaceæ and Bignoniaceæ, differing from the former in the exalbuminous seeds, from the latter chiefly, so far as written characters can be given, in the structure of the placenta and in the seeds not being winged. Generally speaking, the large bracts of the inflorescence, and the imbricated calyx of unequal sepals, give a peculiar and characteristic appearance to these plants. The seeds of *Acanthodium*, *Ruellia*, and other species have a testa clothed with curious compound hairs containing spiral fibres.

**Distribution.**—A large Order, chiefly tropical.

**Qualities and Uses.**—Mostly without active properties. The most striking peculiarity lies in the beauty of the flowers of many kinds, which renders them great favourites in our stoves. *Acanthus mollis* is interesting from its leaves having, it is said, furnished the model of the Corinthian capital.

## ORDER CVIII. BIGNONIACEÆ. THE TRUMPET-FLOWER ORDER.

*Class.* Personatæ, *Endl.* *All.* Bignoniales, *Lindl.* *Coh.* Personales, *Benth. et Hook.*

466. *Diagnosis.*—Woody, or rarely herbaceous plants, often twining or climbing, with exstipulate leaves, hypogynous monopetalous corollas, didynamous or diandrous stamens; the ovary commonly 2-celled, by the meeting of the 2 placentas or of projections from them, surrounded at the base by a disk; many-seeded; the seeds large, winged, with a flat embryo, and no albumen.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Bignonia, *L.* | Catalpa, *Scop.* |
| Tecoma, *Juss.* | Eccremocarpus, *R. & P.* |

**Affinities.**—The exalbuminous character of the seeds separates this Order from Scrophulariaceæ. From Acanthaceæ there is less marked distinction; but the winged and sessile seeds, together with the general habit of the inflorescence, mark the difference. *Eccremocarpus* approaches closely to Gesneraceæ; and these, with Pedaliaceæ and Crescentiaceæ, are chiefly separated by the want of coherence of the placentas in the axis (the exceptional case here in *Eccremocarpus*) and the absence of a wing to the seeds. Many Bignoniaceæ are remarkable for the structure of their woody stems, which have the wood divided into segments by broad wedge-shaped processes of the bark: the segments are 4 in young stems, forming a cross in the transverse section; 8, and even 16 lobes appear in the woody layers of subsequent years. The broad paper-like wing of the seeds of *Bignoniæ* has a very elegant microscopic structure.

**Distribution.**—A considerable family of mostly tropical plants; the Trumpet-flowered climbers form striking features of American forests.

**Qualities and Uses.**—Many of the plants of this Order are used in Brazil for various purposes, such as dyes, medicines of varied action, timber, &c.; but none are of very great importance. Their beautiful flowers, often large and brightly coloured, render them very attractive. *Tecoma radicans, Eccremocarpus scaber*, &c. are common garden climbers; *Catalpa syringæfolia* is a handsome tree with showy blossoms, hardy in this country.

(PEDALIACEÆ are chiefly distinguished from Bignoniaceæ by their generally wingless seeds, and by their different habit. *Sesamum* may be regarded as intermediate between the Orders just named, while *Martynia* establishes a transition to Gesneraceæ, of which Order Pedaliaceæ, or, as they are sometimes called, Sesameæ, are considered by some to form a tribe. They are chiefly tropical; the most important member of the group is *Sesamum orientale*, which is an object of cultivation in the East for its seeds, from which oil resembling Olive-oil is obtained. Some of the species are in cultivation, among them one or two species of *Martynia* remarkable for the two long horns to the fruit.)

(Crescentiaceæ are also very near to the Gesneraceæ, and chiefly separated by the arborescent habit and large amygdaloid seeds; the calyx also is free, and its limb splits irregularly. From Pedaliaceæ the fruits and the amygdaloid seeds divide them. The indehiscent fruit and wingless seeds separate them from Bignoniaceæ and Acanthaceæ, and this, together with the want of albumen, from Scrophulariaceæ, Solanaceæ, and Lentibulaceæ. This Order is tropical, most developed in the Mauritius and Madagascar. *Crescentia Cujete*, the Calabash-tree, has a fruit like a gourd, with a hard shell applicable to many useful purposes, holding liquids, forming floats for rafts, &c. The subacid pulp is eaten. *Parmentiera cerifera* (Panama) has a long slender fruit, and is called, from the shape of this, the Candle-tree; it is a favourite food of cattle.)

## Order CIX. GESNERACEÆ.

*Class.* Personatæ, *Endl.* *All.* Bignoniales, *Lindl.* *Coh.* Personales, *Benth. et Hook.*

467. *Diagnosis.*—Soft woody shrubs or herbs, somewhat succulent, with opposite or whorled wrinkled leaves, without stipules; flowers irregular; corolla perigynous or hypogynous, monopetalous; stamens diandrous or didynamous with a rudimentary 5th; ovary half-superior, with a ring of glands or a disk, 1-celled, with two 2-lobed parietal placentas; fruit capsular or succulent; seeds numerous, with or without albumen; cotyledons much shorter than the radicle.

### Illustrative Genera.

| | |
|---|---|
| Suborder 1. Gesnereæ. *Seeds with a little albumen; calyx partly adherent to the capsular fruit.* | Suborder 2. Cyrtandreæ. *Seeds without albumen; fruit free, capsular, twisted, or baccate.* |
| Gesnera, *Mart.* | Æschynanthus, *Jack.* |
| Achimenes, *P. Br.* | Streptocarpus, *Lindl.* |
| Gloxinia, *Hérit.* | Cyrtandra, *Forst.* |

**Affinities, &c.**—The Gesneraceæ have much the aspect of Scrophulariaceæ; and the flowers very much resemble those of Bignoniaceæ, but their placentas are decidedly parietal; and although *Eccremocarpus* connects them with Bignoniaceæ, its winged seeds and large cotyledons still mark the difference from Gesneraceæ. The parietal placentas resemble those of Orobanchaceæ, which connect the Order further with Scrophulariaceæ; but in the *Gesnereæ*, where the seeds are albuminous, the calyx is more or less adherent to the ovary. They are tropical plants:—the *Gesnereæ* American; the *Cyrtandreæ* more diffused, but chiefly Eastern. They are of no great importance as regards their properties: some *Gesneræ* have edible fruits: the most interesting point about them is the beauty of the flowers. Most of the genera above cited are found in collections of stove-plants; in their native habitations they are often epiphytic.

## ORDER CX. OROBANCHACEÆ. BROOM-RAPES.

*Class.* Personatæ, *Endl.* *All.* Gentianales, *Lindl.* *Coh.* Personales, *Benth. et Hook.*

468. *Diagnosis.*—Fleshy herbs destitute of green foliage (root-parasites); corolla monopetalous; stamens irregular, hypogynous, didynamous; the ovary 1-celled, with 2–4 parietal placentas; capsule with very numerous seeds, which are minute, albuminous, with a very small rudimentary embryo.

### ILLUSTRATIVE GENERA.

Orobanche, *L.* | Lathræa, *L.*

**Affinities, &c.**—This Order is especially remarkable for the parasitic habit, the fleshy texture, scale-like leaves, and the absence of chlorophyll, in which particulars the plants resemble Monotropaceæ; but these are not characters of ordinal value, and we see them running into the nearest allies of this group, as *Buchnera* and *Striga* in Scrophulariaceæ, not to mention the partially parasitic condition of *Melampyræ.* The Order is chiefly separated from Scrophulariaceæ by its parietal placentas. From Gentianaceæ it differs in the carpels being placed back and front, as in Scrophulariaceæ and the allied Orders, while in Gentianaceæ they are right and left of the axis. From Gesneraceæ there is little except the habit to separate them. These plants are parasitic on the roots of many herbs and shrubs of very various Orders; they attach themselves immediately after germination, and become organically grafted; some increase by tuberous buds from the base of the annual stems. The Orobanchaceæ are bitter and astringent, and are said to be escharotic; these qualities probably depend on a resinous fluid secreted in the abundant epidermal hairs. They are comparatively numerous in Europe, North America, North Asia, and the Cape; some in India.

## ORDER CXI. SCROPHULARIACEÆ.

*Class.* Personatæ, *Endl.* *All.* Bignoniales, *Lindl.* *Coh.* Personales, *Benth. et Hook.*

469. *Diagnosis.*—Chiefly herbs; flowers with hypogynous, monopetalous, irregular corollas, the lobes of which are imbricate in æstivation; didynamous, diandrous (or very rarely 5 perfect) stamens attached to the tube of the corolla; ovary 2-celled, cells antero-posterior; fruit a 2-celled, mostly many-seeded capsule with axile placentas; seeds anatropous; embryo small, in copious albumen.

### *Character.*

*Calyx* persistent, more or less deeply 3–5-toothed, more or less irregular.

*Corolla* monopetalous, irregular; the tube long or short; the limb more or less deeply 5-lobed, or 4-lobed by the coherence of the 2 posterior petals, personate (fig. 400), bilabiate, rotate (fig. 399), sometimes spurred.

*Stamens* 2, 4, and didynamous (fig. 403), or with the 5th (posterior) perfect, sterile, or represented by a petaloid tooth (fig. 401), attached to the corolla; *anthers* 2-celled, or 1-celled by confluence or by suppression.

*Ovary* 2-celled, with axile placentas bearing usually numerous ovules; *style* and *stigma* simple, or bifid at the apex.

*Fruit* capsular, rarely baccate, 2-celled, dehiscing by 2 or 4 valves, or by pores, or indehiscent; *seeds* mostly numerous, albuminous.

Fig. 399.

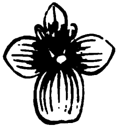


Fig. 401.

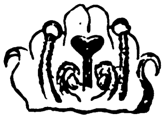


Fig. 403.

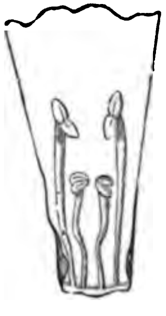


Fig. 400.

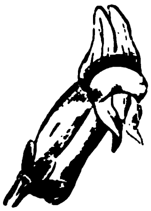


Fig. 402.

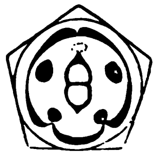


Fig. 399. Corolla and stamens of *Veronica*.
Fig. 400. Calyx and corolla of *Antirrhinum*.
Fig. 401. Corolla, laid open, with didynamous stamens and staminode, of *Scrophularia*.
Fig. 402. Diagram of flower of *Scrophularia*.
Fig. 403. Didynamous stamens of *Digitalis*.

ILLUSTRATIVE GENERA.

*Salpiglossis, *R. & P.*
*Schizanthus, *R. & P.*
Calceolaria, *Feuill.*
Verbascum, *L.*
Linaria, *Tournef.*
Antirrhinum, *L.*
Paullownia, *Zucc.*
Scrophularia, *Tournef.*
Pentstemon, *L'Hérit.*
Mimulus, *L.*
Limosella, *L.*
Digitalis, *L.*
Veronica, *L.*
Bartsia, *L.*
Euphrasia, *L.*
Rhinanthus, *L.*
Pedicularis, *L.*
Melampyrum, *L.*

**Affinities.**—This large Order exhibits considerable variety of conditions, whence its affinities become somewhat complex. It is frequently divided into three Suborders, thus:—

1. *Salpiglossideæ.* Æstivation of corolla plicate or imbricate, two posterior lobes outside.

2. *Antirrhineæ.* Corolla bilabiate, imbricate in æstivation, the posterior one outside the anterior one.

3. *Rhinantheæ.* Æstivation imbricate, the two lateral lobes or one of them placed outside.

The near connexion with Solanaceæ, shown in the close relationship between *Salpiglossis* and *Petunia*, is mentioned also under that Order, where a reference is made to the proposed transfer of the *Salpiglossidæ* (marked above with an *) to the Order Atropaceæ of Miers. Mr. Bentham defines the present Order by referring to Solanaceæ the genera which have at once 5 stamens and a corolla plaited in æstivation; *Petunia* has a plaited corolla and 5 stamens, which, however, are unequal and declinate, and thus approach to *Salpiglossis*, where the corolla is very similar, but the stamens truly didynamous. *Verbascum*, having 5 stamens, is sometimes referred to Solanaceæ; but one at least of the stamens is commonly sterile, and its corolla is imbricated. In another direction, Scrophulariaceæ approach some of the forms of the very heterogeneous Loganiaceæ, and Bentham regards it as advisable to refer *Buddleia* and its allies, generally counted among Scrophulariaceæ, to that Order, as the only means of setting a definite boundary between the Orders, these genera having a transverse ridge connecting their opposite leaves—an indication of the characteristic interpetiolar stipules of Loganiaceæ. With Orobanchaceæ, again, the connexion is close, especially through the root-parasitism of many genera, all of which approach closely in the general structure of the flower to *Orobanche*: for the carpels are really anterior and posterior in that Order as they are here, and the main distinction is, that the margins are not folded-in to form a dissepiment, so that Orobanchaceæ have parietal instead of axile placentation; to which is added their minute rudimentary embryo. A general resemblance exists between the present Order and the other didynamous monopetalous Orders; but Gesneraceæ, Pedaliaceæ, and Crescentiaceæ have parietal placentas; Bignoniaceæ and Acanthaceæ have exalbuminous seeds, and Lentibulaceæ a free central placenta.

The morphology of the corolla in this Order is well deserving of attention: curious monstrosities not unfrequently occur in cultivation, in which the normal irregularity is obliterated by a repetition of the pouches, spurs, or similar developments in each constituent petal, as in *Linaria*, where a 5-spurred corolla occurs with a symmetrical limb (Pelorian variety)—in this instance the regularity is due to the increased number of the usually irregular parts (in other cases the flower becomes perfectly regular by the complete absence of pouches and spurs),—*Calceolaria* with a somewhat campanulate, regular corolla, &c. Many of the Scrophulariaceæ are parasitic upon the roots of other plants, as, for example, *Melampyrum*, *Rhinanthus*, and their allies, which, however, appear to be only partly nourished in this way, having distinct roots; they are remarkable for turning black when dried; *Striga*, an exotic genus, is still more distinctly parasitical; and *Buchnera hydrabadensis* has scale-like leaves similar to those of *Orobanche*. In some of the genera (*Mimulus* &c.), where the style is divided at the apex, it is developed into two flat laminæ, which exhibit irritability.

**Distribution.**—A very large group, the species of which are universally diffused and very abundant.

**Qualities and Uses.**—More or less acrid, or bitter; mostly unwholesome; sometimes deadly poisons. *Digitalis purpurea*, our native Foxglove, the officinal plant, is an extremely powerful sedative poison, both in the foliage and the seeds; the allied species *D. lutea*, *ochroleuca*, *lævigata*, &c. are equally active. The species of *Verbascum* have a share of this property, especially in the seeds. The *Scrophulariæ*, *Linariæ*, and *Veronicæ* are all more or less bitter and acrid, and suspicious; *Gratiola* violently purgative and emetic.

This Order is remarkable for the number of beautiful flowering herbs it contains. The Snap-dragon, or Dragon's-mouth (*Antirrhinum majus*), the species of *Veronica*, *Mimulus* (of which the Musk-plant, *M. moschatus*, is remarkable, among plants of this order, for its fragrance), *Linaria*, *Pentstemon*, *Calceolaria*, *Maurandya*, &c. are in every garden; and of their numerous exotic allies a long list will be found in all horticultural collections. A large number of showy-flowered native weeds belong to this Order, such as the Toad-flax (*Linaria vulgaris*) and several other species of *Linaria*, the Speedwells (*Veronica*), the Red Rattle (*Pedicularis*) and the Yellow Rattle (*Rhinanthus*) (so called from the ripe seeds rattling in the dried inflated membranous capsules), the Foxglove, Mulleins (*Verbascum*), &c.

## ORDER CXII. LENTIBULACEÆ. BUTTER-WORTS.

*Class.* Personatæ, *Endl.* *All.* Bignonales, *Lindl.* *Coh.* Personales, *Benth. et Hook.*

470. *Diagnosis.*—Small herbs growing in water or wet places; flowers with a 2-lipped calyx and a non-hypogynous 2-lipped personate corolla; stamens 2, with (confluent) 1-celled anthers; ovary 1-celled, with a free central placenta bearing several anatropous seeds, with a thick straight embyo and no albumen; stigma bilabiate.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Utricularia, *L.* | Pinguicula, *Tournef.* |

**Affinities.**—This Order is interesting, both from the habits and appearance of the plants, and from its affinities:—on the one hand with the irregular, didynamous monopetalous Orders, through Scrophulariaceæ, with which it agrees in the calyx, corolla, and stamens; and on the other hand with the regular Monopetalæ, through Primulaceæ, with which it is connected by the free central placenta. The structure of the leaves of the *Utriculariæ*, especially that of their pouches or air-floats (fig. 405), is very curious. The plants are found in all parts of the globe; the *Utriculariæ* are aquatic, one curious Brazilian species (*U. nelumbifolia*) growing in the water retained in the axils of the sheathing leaves of a *Tillandsia*. *Pinguiculæ* are bog-plants; and *P. vulgaris* is said to have the property of coagulating milk.

Fig. 404.

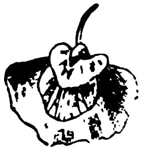


Fig. 405.

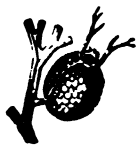


Fig. 404. Flower of *Utricularia.*
Fig. 405. Air-sac of the leaf of *Utricularia.*

## SUBCLASS 4. INCOMPLETÆ.

471. Dicotyledonous plants with a green or coloured calyx and no petals, or with a calyx-like perianth of more than one whorl, or with the floral envelopes reduced to one or more bract-like pieces, or altogether absent. Flowers often unisexual.

The above characters are more or less artificial, and bind together a rather heterogeneous series of orders. Many of them are merely degraded forms of Thalamifloral or Calycifloral types. The group is sometimes divided into two subdivisions, called Monochlamydeæ and Achlamydeæ, according as there is or is not a true calyx or perianth surrounding the stamens and pistil. Many of the plants in this group have unisexual flowers grouped in cones or catkins.

### ORDER CXIII. POLYGONACEÆ. THE SORREL ORDER.

*Class.* Oleraceæ, *Endl.* *All.* Silenales, *Lindl.* *Coh.* Chenopodiales, *Benth. et Hook.*

472. *Diagnosis.*—Herbs with alternate leaves, mostly furnished with stipules in the form of sheaths (*ocreæ*) above the swollen joints of the stem; the flowers mostly perfect, with a more or less persistent perianth; stamens hypogynous, or very rarely perigynous; a 1-celled ovary bearing 2–3 styles or stigmas, and a single erect orthotropous ovule; fruit a triangular nut enclosing 1 erect seed, usually with farinaceous albumen and an inverted embryo.

ILLUSTRATIVE GENERA.

Eriogonum, *L. C. Rich.*
Rheum, *L.*
Polygonum, *L.*
Coccoloba, *Jacq.*
Rumex, *L.*

**Affinities.**—The commoner plants of this Order may be distinguished by the peculiar ocreaceous stipules (fig. 58), which, however, are wanting in *Eriogonum* and some other genera; the most distinctive characteristic is the solitary erect seed with its embryo having the radicle turned upward; this separates it from its near allies, the Chenopodiaceæ and Amarantaceæ, from which also the perianth and the ocreæ remove it; also from the Nyctaginaceæ, to which the involucrate flowers and abortive stipules of *Eriogoneæ* approach. There is a further relation to Caryophyllaceæ through the Paronychiaceæ.

**Distribution.**—A large Order, the members of which are universally diffused, especially abundant in temperate climates.

**Qualities and Uses.**—The foliage of these plants is frequently characterized by the presence of an acid juice, depending on the presence of oxalic and malic acids, or by an acrid, pungent juice; some are strongly astringent, while the roots are generally more or less powerfully purgative; the starchy albumen of the seeds is sufficiently abundant in some species to furnish a valuable substitute for corn. Among the useful acidulous kinds are the garden Rhubarb, *Rheum undulatum*, *R. palmatum*, &c.; the Sorrels (*Rumex scutatus*, *R. Acetosa*, and *R. Acetosella*) are familiar plants. *Rheum Ribes* is used for flavouring sherbet in the East; and some other exotic plants have like properties. *Polygonum Hydropiper*, a common native weed, is very acrid, even vesicant when fresh. *P. Bistorta* was formerly in use as an astringent; and *Coccoloba uvifera*, the Sea-side Grape of the West Indies, furnishes a very astringent extract. The Rhubarb of medicine consists of the roots of *Rheum palmatum*, *undulatum*, *rhaponticum*, *Emodi*, *Webbianum*, and other species; the roots of *Rumex alpinus* were formerly used as a purgative under the name of Monk's Rhubarb. *Fagopyrum esculentum*, common Buck-wheat, *F. tataricum*, and other species are largely cultivated for food in the northern parts of Asia and of Eastern Europe. The common Docks are species of *Rumex*.

## ORDER CXIV. NYCTAGINACEÆ. THE MARVEL-OF-PERU ORDER.

*Class.* Oleraceæ, *Endl.* *All.* Chenopodales, *Lindl.* *Coh.* Nyctaginales, *Benth. et Hook.*

473. *Diagnosis.*—Herbs, shrubs, or trees, mostly with opposite and entire leaves; stems tumid at the joints; flowers surrounded by an involucre, with a delicate, tubular or funnel-shaped petaloid perianth; upper part deciduous, lower part persistent, constricted above the 1-celled, 1-seeded ovary, and indurated to form the pericarp (diclesium); stamens 1 or several, slender, hypogynous; the embryo coiled round the outside of the mealy albumen, with broad foliaceous cotyledons and an inferior radicle.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Boerhaavia, *L.* | Mirabilis, *L.* | Pisonia, *Plum.* |

**Affinities.**—The nearest relatives of these plants are probably the Polygonaceæ, especially the tribe of *Eriogoneæ*; but the inferior radicle and the peculiar fruit enclosed in the indurated base of the perianth are evident distinctions. The stems of these plants, especially of the *Pisoniæ*, have a curious arrangement of their fibro-vascular bundles.

**Distribution.**—Natives of warm climates, chiefly in the S. hemisphere.

**Qualities and Uses.**—The roots of the Nyctaginaceæ are generally purgative; and *Mirabilis Jalapa* was formerly supposed to be the source of medicinal Jalap. *Mirabilis dichotoma*, the Marvel of Peru of our gardens is remarkable for opening its flowers in the afternoon, whence it is termed the Four-o'clock Plant; both this and *M. longiflora*, another cultivated species, are violent purgatives.

## ORDER CXV. AMARANTACEÆ. AMARANTHS.

*Class.* Oleraceæ, *Endl.* *All.* Chenopodales, *Lindl.* *Coh.* Chenopodiales, *Benth. et Hook.*

474. *Diagnosis.*—Weedy herbs, with opposite or alternate exstipulate leaves, and spiked or capitate, bracteated inflorescence; the flowers mostly with an imbricated perianth of dry and scarious persistent bracts, often coloured, 3–5 in number; occasionally unisexual; stamens 5-merous, hypogynous; anthers sometimes 1-celled; the one-celled ovary usually 1-ovuled, in one tribe (Celosieæ) many-ovuled; style 1 or 0; stigma simple or compound; fruit a utricle, a caryopsis, or a berry; seed pendulous, with the embryo curved round the circumference of farinaceous albumen; the radicle near the hilum.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Celosia, *L.* | Achyranthes, *L.* |
| Amarantus, *L.* | Gomphrena, *L.* |

**Affinities.**—No absolute character can be given to separate this Order from the Chenopodiaceæ; but the habit, especially the crowded bracteated inflorescence and the membranous perianth, renders them very different in appearance. Their more distant relations are the same as those of that Order.

**Distribution.**—A large Order, the species of which are most abundant within the tropics, in dry, barren situations.

**Qualities and Uses.**—Generally with somewhat mucilaginous juice, seldom with active properties. The species of *Amarantus*, such as *A. caudatus*, Love-lies-bleeding, and *A. hypochondriacus*, Prince's-Feathers, are well known in gardens for their bright-coloured and persistent blossoms—as are also the more tender Globe Amarantus (*Gomphrena*) and the Cock's-comb (*Celosia cristata*), the latter remarkable for its fasciated flowering-stem.

## ORDER CXVI. CHENOPODIACEÆ. THE SPINACH ORDER.

*Class.* Oleraceæ, *Endl.* *All.* Chenopodales, *Lindl.* *Coh.* Chenopodiales, *Benth. et Hook.*

475. *Diagnosis.*—Chiefly herbs, of weedy aspect, more or less succulent; leaves mostly alternate; no stipules, nor scarious bracts; flowers perfect, polygamous or diclinous, minute, greenish, with the free perianth imbricated in the bud; the stamens as many as the perianth-lobes, or rarely fewer, and inserted opposite to them or on their bases; the 1-celled ovary becoming a 1-seeded thin utricle or an achænium; embryo coiled into a ring (around the albumen when present) or spiral.

### Illustrative Genera.

Salicornia, *Tournef.*
Atriplex, *L.*
Blitum, *L.*
Beta, *Tournef.*
Chenopodium, *L.*
Salsola, *L.*

**Affinities.**—Closely related to Amarantaceæ, but differing in habit and in the sum of the characters. From the Phytolaccaceæ they differ in the simple ovary and the stamens equal in number and opposite to the segments of the perianth; from *Sclerantheæ* they are separated by the simple ovary, the usually alternate leaves, and the distinctly hypogynous condition of the stamens; from the *Paronychieæ* particularly by the absence of stipules; through the Paronychiaceæ they are nearly related to Caryophyllaceæ.

**Distribution.**—A large Order, generally diffused in waste places or in salt-marshes; most abundant outside the tropics.

**Qualities and Uses.**—Generally bland and innocuous, the foliage often rendering them valuable as pot-herbs, and their roots furnishing food for cattle; sometimes with anthelmintic and antispasmodic properties. The maritime kinds were formerly of great value from the quantity of soda obtained from their ashes. Spinach (*Spinacia oleracea*), Orach (*Atriplex hortensis*), and English Mercury (*Chenopodium Bonus Henricus*) belong to this Order; also the Beet and Mangold Wurzel (*Beta vulgaris* and *Cycla*). From the juice of the Beet, sugar is extracted in considerable quantities. *Chenopodium anthelminticum* yields an essential oil, used as an anthelmintic under the name of Worm-seed Oil; *C. ambrosioides* and *Botrys* also have an aromatic, antispasmodic essential oil; *Chenopodium Quinoa* forms tubers like potatoes, which are eaten in Peru. *Salsola Soda*, *Salicornia herbacea*, and other species (Glass-wort), with species of *Atriplex*, *Schoberia*, &c., abound in salt-marshes, and were formerly much used in the preparation of barilla. Several species of *Chenopodium* and *Atriplex* abound in waste places, forming, with various kinds of Dock (*Rumex*), *Polygonum*, and *Urtica* (Nettle), the most conspicuous weeds of neglected cultivated ground.

(Basellaceæ are a small Order of plants closely related to Chenopodiaceæ, chiefly distinguished by the presence of a double, coloured perianth and perigynous stamens; they are tropical climbing herbs or shrubs. Some species of *Basella* are used as Spinach; *Ullucus tuberosus* has a tuberous root, used in Peru like the Potato.)

(Phytolaccaceæ proper are nearly connected with Polygonaceæ and Chenopodiaceæ, differing from both in the presence of a number of carpels, from the former also in the absence of stipules, from the latter in the stamens exceeding the lobes of the perianth. *Phytolacceæ* pass into *Petiverieæ* by the occurrence of 5 separate carpels in *Giesekia*, while *Rivina* has little albumen; the *Petiverieæ* would then connect this Order with the Sapindaceæ and their allies, while the columella of the *Gyrostemoneæ* would mark a distant affinity with the Malvaceæ.

**Distribution.**—A small Order, scattered in all parts of the world.

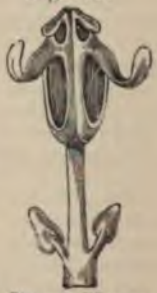
**Qualities and Uses.**—More or less acrid, purgative, or emetic.)

(Petiverieæ, separated by some authors, have stipulate leaves, single ovary, exalbuminous seeds, and a straight embryo with convolute cotyledons; and Gyrostemoneæ have unisexual flowers, the carpels arranged round a columella, twin suspended ovules, albuminous seeds, with a hooked embryo having linear cotyledons, and an inferior radicle.)

## ORDER CXVII. LAURACEÆ. THE BAY ORDER.

*Class.* Thymeleæ, *Endl.* *All.* Daphnales, *Lindl.* *Coh.* Laurales, *Benth. et Hook.*

Fig. 406.



Stamen of *Laurus.*

476. *Diagnosis.*—Aromatic trees or shrubs, with alternate simple leaves, sometimes marked with pellucid dots, and flowers with a regular perianth of 4–6 coloured sepals, which are barely united at the base, imbricated in 2 circles in the bud, free from the 1-celled ovary containing 1 or 2 pendulous ovules, and mostly fewer than the stamens; anthers opening by 2 or 4 lid-like valves (fig. 406); fruit a berry or a drupe; seed without albumen; radicle superior.

### ILLUSTRATIVE GENERA.

Cinnamomum, *Burm.*
Camphora, *Nees.*
Nectandra, *Rottl.*

Sassafras, *Nees.*
Tetranthera, *Jacq.*

Laurus, *Tournef.*
Cassytha, *L.*

**Affinities.**—The peculiar operculate dehiscence of the anthers distinguishes this Order from most of the allied Monochlamydeous groups: from Atherospermaceæ, which share this character, Lauraceæ are distinguished by their solitary carpel and pendulous ovules. The Lauraceæ have also affinities with Myristicaceæ in the qualities of their products; but the structure differs widely. *Cassytha* is a remarkable form, having a twining parasitic leafless stem like *Cuscuta*, bearing true Lauraceous flowers. The fruit of some genera is curious, as that of *Dehaasia*, which is borne upon a thickened peduncle, somewhat like that of *Anarcardium.*

**Distribution.**—A large Order, principally found in cool situations in the tropics; one (*Laurus nobilis*) is a native of Europe, and a few of North America.

**Qualities and Uses.**—The most marked properties of these plants depend on the presence of aromatic oils and Camphor; but the bark of some has valuable tonic and febrifuge qualities, the timber of many kinds is valuable, and the Order affords a number of edible fruits.

True Cinnamon is the bark of *Cinnamomum zeylanicum*; Cassia-bark is derived from *C. Cassia* and other species; many other trees of the Order are noted for the possession of an aromatic bark of similar character, and furnish false Cinnamons in South America and other countries. Camphor is produced in the wood, branches, and leaves of *Camphora officinarum*, and is obtained by dry distillation; some species of *Cinnamomum* contain a considerable quantity of this substance. The aromatic fruits of some of the Lauraceæ furnish false Nutmegs, the Clove-nutmegs of Madagascar being the seeds of *Agathophyllum aromaticum*, the Brazilian Nutmegs those of *Cryptocarya moschata*, &c.

The bark of *Nectandra Rodiæi*, the Bibiri of Guiana, is said to be a valuable febrifuge; the bark of the root of *Sassafras officinale* is highly esteemed in North America for its diaphoretic powers; *Benzoin odoriferum* has similar properties, and the oil of its aromatic berries is stimulant. The fruit of *Persea gratissima* is the highly praised West-Indian Avocado Pear; it contains much fixed oil.

The timber of *Nectandra Rodiæi* is the Green-heart wood of Guiana, remarkable for its hardness and solidity; *Persea indica* furnishes a kind of coarse mahogany in the Canaries. Camphor-wood is sometimes used by cabinet-makers on account of its odour. *Laurus nobilis*, the Bay-tree or classic Laurel, is a native of the South of Europe, and is hardy in the south of England; its aromatic leaves are used for flavouring confectionary (these must not be confounded with those of the Cherry-laurel, which contain much hydrocyanic acid); a concrete green oil, called Oil of Bays, is obtained from it.

(The ATHEROSPERMACEÆ are trees like Monimiaceæ, but with the flowers sometimes perfect, the anthers opening by lid-like valves, and the albuminous seeds erect; the nuts are enclosed in the tube of the perianth, and the persistent styles grow out into feathery awns, whence the plants are called Plume-nutmegs. They are chiefly distinguished from Monimiaceæ by their anthers, which resemble those of Lauraceæ, from which they are distinguished by the apocarpous ovaries, the diclinous flowers, and erect albuminous seeds, and are allied to Myristicaceæ by the diclinous flowers and aromatic albuminous seeds. The valvate anthers here, as observed by Dr. Hooker, indicate affinity to Berberaceæ rather than to Lauraceæ. Two of the genera, *Laurelia* and *Atherosperma*, are natives of Australia; *Doryphora* is Chilian; they have fragrant properties, and a decoction of the bark of *A. moschata* is sometimes used as a substitute for Tea.)

## ORDER CXVIII. MYRISTICACEÆ.
### THE NUTMEG ORDER.

*Class.* Polycarpicæ, *Endl.* *All.* Menispermales, *Lindl.* *Coh.* Laurales?, *Benth. et Hook.*

477. *Diagnosis.*—Tropical trees with alternate, entire, leathery, exstipulate dotted leaves; flowers diclinous, apetalous, clustered or racemose; perianth 3- or rarely 4-fid, leathery, valvate; stamens of the barren flower distinct or monadelphous; anthers 3–12, perfect, extrorse; perianth of the fertile flower deciduous; carpels solitary or numerous, rarely 2, and distinct; ovules 1 in each cell; fruit succulent, containing a seed surrounded by a lobed arillus, and having a small embryo in copious oily-fleshy ruminated albumen.

ILLUSTRATIVE GENERA.

Myristica, *L.* | Hyalostemma, *Wall.* | Virola, *Aubl.*

**Affinities.**—The nearest relations of this Order are with the apocarpous Thalamiflorous Orders, more particularly Anonaceæ, with which they agree in the dotted leaves, valvate æstivation, extrorse anthers, apocarpous ovaries and ruminated albumen; but the flowers are usually perfect in that Order. The structure of the seeds connects Monimiaceæ and Atherospermaceæ with this Order; but they have opposite leaves, besides other peculiarities. In many points they resemble Magnoliaceæ, but differ in the valvate calyx, absence of corolla, monadelphous stamens, solitary carpel and ovule. [The resemblance to Sterculiaceæ seems to have been overlooked; nevertheless there are many points of contact between the present family and the tribe Sterculieæ, in the apetalous unisexual flowers, the valvate calyx, the monadelphous stamens, the arillate seeds.—Ed.]. In their active qualities and habit they somewhat resemble Lauraceæ.

**Distribution.**—Tropical India and America; most numerous in the former.

**Qualities and Uses.**—Aromatic and acrid. The common Nutmeg is the seed of *Myristica moschata* (Moluccas), Mace being the laciniated arillus surrounding this. Coarse, inferior Nutmegs are obtained from *M. Otoba* in Brazil, *M. spuria* in the Indian islands, and others of the numerous American and East-Indian species. The bark and the rind of the fruit are acrid.

(Lacistemaceæ are a small group of shrubs belonging to the woods of tropical America, with apetalous, polygamous or diclinous flowers, and a 1-celled ovary with parietal placentas. Their position is doubtful; they have an amentaceous inflorescence, a perianth like that of Urticaceæ, filaments like those of Chloranthaceæ, and an ovary like that of Samydaceæ or Bixaceæ, with arillate seeds as in the latter Order.)

(Garryaceæ.—A small Order of shrubs of North-west America, and having amentaceous inflorescence, unisexual flowers, a 2–4-parted perianth, definite stamens, and a 1–3-celled inferior ovary with 2 pendulous ovules; seeds with a minute embryo in abundant albumen. They differ from Hamamelidaceæ in their apetalous flowers, definite stamens, and baccate fruit.)

(Helwingiaceæ is an Order founded on a Japanese shrub which bears the fascicles of flowers adherent to the midribs of the leaves (?); it differs from Garryaceæ in having the inferior ovary 3–4-celled, with an ovule in each cell. These plants are usually placed among diclinous Monochlamyds, but they appear to have relations with Santalaceæ, Hamamelidaceæ, and Cornaceæ. They have no important properties.)

## Order CXIX. LORANTHACEÆ. The Mistletoe Order.

*Class.* Discanthæ, *Endl.* *All.* Asarales, *Lindl.* *Coh.* Santalales, *Benth. et Hook.*

478. *Diagnosis.*—Shrubby plants with leathery greenish foliage, parasitic (naturally grafted) on trees; leaves opposite, exstipulate; flowers perfect or diclinous; perianth adherent, with 4–8 lobes; stamens 4–8, opposite to the segments of the perianth; ovary inferior, 1-celled, with 3 ovules pendulous from a free central placenta, or

1, erect, arising from the base of the cell; fruit succulent; seed 1; embryo in fleshy albumen; radicle remote from the hilum.

ILLUSTRATIVE GENERA.

Viscum, *Tournef.* | Loranthus, *L.* | Myzodendron, *Sol.*

**Affinities.**—These remarkable plants are distinguished by their peculiar parasitic habit. They are nearly allied to Santalaceæ, presenting, like that Order, a naked nucleus as the representative of the ovule, and are further characterized by the strange extrusion of the apex of the embryo-sac before or after fertilization. Besides the curious structure of the flowers, they have an anomalous organization of the wood, which has no medullary sheath of spiral vessels, but contains scalariform tubes. The germination of the seeds exhibits some interesting phenomena: in *Viscum* the seeds adhere to the young shoots of trees by means of the viscid pulp of the fruit; in *Myzodendron* there are long feathered processes, which coil round the branches on which they settle; in either case the seeds are retained in contact with the surface of the shoot upon which they rest, where they germinate and push their radicle through the bark, down to the cambium-layer, with which they contract an organic adhesion and become grafted, just as a bud does in the ordinary gardening operation of budding Roses, &c.

**Distribution.**—A large Order, of which some are European, as *Viscum album* and *Loranthus europæus*; the majority belong to the hotter parts of Asia and America; *Myzodendron* belongs to the temperate parts of the southern hemisphere.

**Qualities and Uses.**—Some of the plants have astringent properties; but the most important product perhaps is the viscid pulp of the fruit of *Viscum album*, which is used for making bird-lime. The curiosity attaching to the parasitic habit is the most striking feature in this Order, most of the plants growing like our common Mistletoe, *Viscum album*; this appears capable of grafting itself on a wide variety of trees, being most common on the Apple-tree with us, but occurring on Thorns, Willows, Limes, Oaks, Elms, and even on Fir-trees.

## ORDER CXX. SANTALACEÆ. THE SANDAL-WOOD ORDER.

*Class.* Thymeleæ, *Endl.* *All.* Asarales, *Lindl.* *Coh.* Santalales, *Benth. et Hook.*

479. *Diagnosis.*—Herbs, shrubs, or trees with entire leaves; the 4–5-cleft perianth valvate in the bud, its tube coherent with the ovary. Stamens opposite to the lobes of the perianth; ovary 1-celled with 2–4 ovules suspended from the apex of a free stalk-like central placenta arising from the base of the cell; the indehiscent fruit 1-seeded; seed with abundant albumen filling the pericarp; embryo straight; radicle superior.

ILLUSTRATIVE GENERA.

Thesium, *L.* | Osyris, *L.* | Santalum, *L.*

**Affinities.**—The definite pendulous ovules, consisting of a naked nucleus attached to a free central placenta and protruding the embryo-sac before or after fertilization, are very remarkable and striking characters in this Order; the entire seed is formed in the embryo-sac, outside the nucleus. The nearest relations are probably with the Loranthaceæ, which, however, differ in habit, being stem-parasites, and having less complete and sometimes imperfect flowers. *Thesium* is partially parasitic on the roots of other plants. There is a more remote relation to Olacaceæ and allied Orders.

**Distribution.**—A small Order; the European and North-American species are inconspicuous herbs; in India and Australia they are shrubs or small trees.

**Qualities and Uses.**—Sandal-wood, the wood of *Santalum album*, is perhaps the best-known production of this Order. The seeds of the Quandang Nut (*Fusanus acuminatus*) are eaten like almonds in Australia. Some species are astringent.

## ORDER CXXI. THYMELACEÆ. THE LACE-BARK ORDER.

*Class.* Thymeleæ, *Endl.* *All.* Daphnales, *Lindl.* *Coh.* Laurales, *Benth. et Hook.*

480. *Diagnosis.*—Shrubs with an acrid and very tough (not aromatic) bark, entire leaves, and perfect flowers, with a regular and simple, usually coloured perianth, bearing ordinarily twice as many stamens as its lobes, free from the 1-celled, 1-ovuled ovary; seed suspended; albumen none, or sparing; radicle superior.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Daphne, *L.* | Lagetta, *Juss.* |
| Pimelea, *Banks & Sol.* | Hernandia, *Plum.* |

**Affinities.**—Among the Monochlamydeous Orders this may be distinguished from Santalaceæ by its free ovary; from Elæagnaceæ by its perfect or polygamous flowers and pendulous seed; from Lauraceæ by the longitudinal dehiscence of the anthers; from Proteaceæ by its pendulous seeds and imbricated perianth. The flowers are mostly perfect, but polygamous in the tribe *Hernandieæ*. The liber is developed in numerous separable layers in the bark of these plants.

**Distribution.**—A rather large Order, most abundant at the Cape of Good Hope and in Australia, but found sparingly in all other parts of the world.

**Qualities and Uses.**—The bark is usually acrid, and that of Mezereon (*Daphne Mezereum*) and other plants is used as a local irritant; taken internally it is an irritant poison. *Daphne Laureola*, the Spurge Laurel, another native species, has similar qualities—as also *D. Gnidium* and *D. pontica*, favourite garden shrubs, and other species. The liber of *Lagetta lintearia* (West Indies) is separable into lace-like laminæ, whence it is called the Lace-bark tree, and the liber of some *Daphnes* furnishes useful fibres, and in other cases is manufactured into paper. The berries of

*Daphne* are poisonous; but the seeds of *Inocarpus edulis* are eaten roasted like chestnuts. *Daphne*, *Pimelea*, and some other genera include many handsome cultivated plants, the perianth being petaloid.

(AQUILARIACEÆ are a small group of plants, of tropical Asia, nearly related to Thymelaceæ, but having a 2-celled ovary, and sometimes a 2-valved dehiscent capsule; one ovule is sometimes abortive; and the fruit in some cases is an indehiscent succulent berry. The heart-wood of *Aquilaria ovata* and *A. Agallochum* are known as Eagle-wood or Aloes-wood, and contains a resinous matter of stimulant quality. Genera: *Aquilaria*, Lam.; *Gyrinopsis*, Gærtn.)

## ORDER CXXII. ELÆAGNACEÆ.

*Class.* Thymeleæ, *Endl.* *All.* Amentales, *Lindl.* *Coh.* Laurales, *Benth. et Hook.*

481. *Diagnosis.*—Shrubs or small trees with silvery-scurfy leaves and mostly diœcious flowers; perianth free from the ovary, its tube becoming pulpy and berry-like in the fruit; stamens as numerous as the lobes of the perianth and alternate with them or twice as many; ovary 1-celled, 1-seeded, seed ascending; embryo straight, with thin albumen and an inferior radicle.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Hippophaë, *L.* | Elæagnus, *L.* |

**Affinities, &c.**—This is a small Order, generally diffused in the northern hemisphere, separated from the Thymelaceæ by the ordinarily diœcious structure and the ascending ovule; *Elæagnus*, which has perfect or polygamous flowers, forms the link. From Proteaceæ they are separated by the valvate calyx and the indehiscent fruit. The scurfy scales upon the leaves are elegant microscopic objects. The berries of *Hippophaë rhamnoides*, Sea Buckthorn, common on our sea-coast, are sometimes used in fish-sauces, but are said to have narcotic properties. Those of *Elæagnus orientalis* are eaten in Persia, and those of other species in India. The flowers of some species are very fragrant.

## ORDER CXXIII. PROTEACEÆ.

*Class.* Thymeleæ, *Endl.* *All.* Daphnales, *Lindl.* *Coh.* Laurales, *Benth. et Hook.*

482. *Diagnosis.*—Shrubs or small trees usually with umbellate branches; leaves hard, dry, opposite or alternate, exstipulate; flowers apetalous; perianth 4-cleft, valvate; stamens 4, opposite to the segments, sometimes partially barren; anthers opening longitudinally; ovary single, simple, free, with 1 ovule, or 2 or more

ovules in 2 rows, ascending; seeds without albumen; embryo straight; radicle inferior.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Protea, *L.* | Hakea, *Schrad.* |
| Grevillea, *R. Br.* | Banksia, *L. fil.* |

**Affinities.**—The remarkable habit of these plants is a striking characteristic; and, besides the rigid foliage, we have the valvate perianth, with the stamens opposite the lobes, and the radicle pointing to the base of the ovary, to distinguish this Order from the Thymelaceæ and nearest Monochlamydeous Orders. The structure of the stomata of the coriaceous leaves is very curious, and presents many modifications.

**Distribution.**—A large Order, the species of which are found chiefly at the Cape and in Australia.

**Qualities and Uses.**—The wood is perhaps the most valuable product of these plants, being largely used for firewood where they abound; sometimes it is used for joinery when hard wood is required. The striking character of their evergreen foliage, and the brilliant colours of the heads of flowers, render them very great favourites in cultivation, and the genera above cited will be found in most large collections of greenhouse shrubs. *Macadamia ternifolia* furnishes an edible fruit.

(PENÆACEÆ are a small Order of Cape evergreen shrubs, related to Proteaceæ, but having a 4-celled ovary, 4 stigmas, and a 4-celled dehiscent or indehiscent capsule. The drug called Sarcocol has been supposed to be derived from some of these plants; but this is doubtful. Genera: *Penæa*, L.; *Sarcocolla*, Kth.; *Geissoloma*, Lindl.)

(EMPETRACEÆ are low shrubby evergreens, with the foliage and aspect of Heaths; the flowers are small, diclinous; the perianth consists of 4–6 persistent hypogynous scales, the innermost sometimes petaloid; stamens 2–3, alternate with the inner scales; ovary free, on a disk, 2–9-celled; ovules solitary; fruit fleshy, with 2–9 nuts; seeds 1 in each nut, ascending, albuminous; radicle inferior. These plants have the appearance of Ericaceæ, the fruit even being like that of *Vacciniecæ*, while the stigmas and the general structure of the flowers are Euphorbiaceous; but from the Euphorbiaceæ they differ in the ascending seed and inferior radicle. They are mostly natives of Northern Europe and North America. The leaves and fruit are slightly acid and agreeable; the berries of *Empetrum nigrum*, the Crow-berry, are eaten; the Greenlanders prepare a fermented liquor from them. The Portuguese use the berries of a *Corema*. Genus *Empetrum*.)

(*Batis maritima*, a succulent shrub, found in the salt-marshes of the West Indies, is sometimes made the type of an Order, but is regarded by Lindley as very close to Empetraceæ. Others place it near to Tamariscineæ. It is sometimes used in West-India pickles).

## ORDER CXXIV. EUPHORBIACEÆ. THE SPURGE ORDER.

*Class.* Tricoccæ, *Endl.* *All.* Euphorbiales, *Lindl.* *Coh.* Euphorbiales, *Benth. et Hook.*

483. *Diagnosis.*—Herbs, shrubs, or trees, mostly with a milky acrid juice, and various, usually monœcious or diœcious flowers; the fruit of 2–3 or several 1–2-seeded carpels, united round a central column, separating when ripe (carpel rarely solitary).

### *Character.*

*Flowers* diclinous, axillary or terminal, sometimes enclosed in a cup-shaped involucre.

*Calyx* inferior, with internal glandular or scaly appendages, sometimes wanting.

*Corolla,* of petals or scales as many as the sepals, or wanting.

*Stamens* definite or indefinite, distinct or monadelphous; *anthers* 2-celled, sometimes opening by pores.

*Ovary* free, sessile or stalked, 1-, 2-, 3-, or many-celled; *styles* as many as the cells, distinct or combined, or wanting; *stigmas* combined or separate and bifid; *ovules* 1 or 2, suspended from the inner angle of each cell.

*Fruit* dry, the carpels splitting and separating elastically from the axis, or succulent and indehiscent; *seeds* suspended, 1 or 2 in each cell, often with an arillus; *embryo* in fleshy albumen; *radicle* superior.

ILLUSTRATIVE GENERA.

Hura, *L.*
Hippomane, *L.*
Cœlebogyne, *J. Sm.*
Mercurialis, *L.*
Acalypha, *L.*

Jatropha, *Kth.*
Ricinus, *Tournef.*
Rottlera, *Roxb.*
Croton, *L.*

Euphorbia, *L.*
Cluytia, *Ait.*
Xylophylla, *L.*
Phyllanthus, *L.*

**Affinities.**—As the more familiar forms of this Order are either apetalous, or even destitute of a calyx, it is usually arranged among the Monochlamydeæ in elementary works; but a large proportion of the exotic genera have the corolla represented either by scales or petals. The common Spurges (*Euphorbia*), the principal native representatives of the Order, have a very remarkable inflorescence, liable to be mistaken for a simple flower: there is a cup-like involucre, within which are formed a number of stamens with an articulation in the filament, together with a stalked tricarpellary ovary (fig. 407). The stamens each represent a male flower reduced to its lowest term; for a minute bract exists at the base of each filament, and in some species a perianth occurs at the articulation, which is, in fact, the base of the flower; the ovary in like manner represents a female flower. This is well illustrated by the exotic genus *Monotaxis* (fig. 408), where the cup-like involucre is replaced by scales, and, instead of the jointed filaments, we find several stalked male flowers, with perianth and stamens, surrounding one female flower.

Fig. 407.

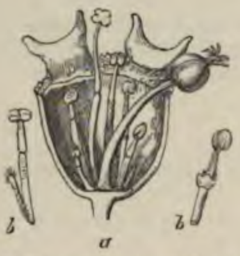


Fig. 408.

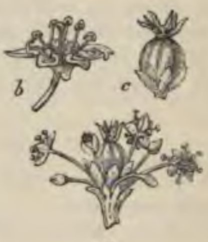


Fig. 407. *a*, Vertical section of the involucre of *Euphorbia Lathyris*, containing one stalked pistillate flower and six monandrous staminate flowers; *b*, *b*, staminate flowers of other species of *Euphorbia*, the left-hand without a perianth, the right with a small perianth at the base of the stamen.

Fig. 408. *Monotaxis tridentata*: *a*, involucre, with one pistillate and several staminate flowers; *b*, a separate staminate, *c*, a separate pistillate flower.

Three is the ordinary number of carpels; but *Mercurialis* has but two, and some exotic genera but one; on the other hand, 9 or even 15 (*Hura*) are occasionally present. The fruit is usually dry and dehiscent, but in *Sarcococca* succulent. Considerable variety of habit occurs; some of the foreign *Euphorbiæ* have fleshy, spiny stems, somewhat resembling those of the Cactaceæ, *Xylophylla* and *Phyllanthus* having leaf-like flowering branches; and a number of large tropical trees belong to this Order.

Were it not for the diclinous structure, these plants would approach very closely to Malvaceæ and their allies, the composition of the ovary being analogous, and the stamens often monadelphous; *Aleurites*, *Jatropha*, and other genera having a corolla much resemble Malvaceæ; and there is a further affinity to Rhamnaceæ. On the other hand, looking to their diclinous character and frequently incomplete flowers, they approach the Urticaceæ, from which they are, as a whole, distinguished by their compound ovaries: such genera as *Eremocarpus*, having but 1 carpel, connect the two groups. Some of the genera have stinging hairs like Urticaceæ (*Jatropha*).

**Distribution.**—A very large Order, generally diffused over the globe; especially abundant in Equinoctial America.

**Qualities and Uses.**—These plants mostly produce a lactescent juice, which contains caoutchouc; the watery part of this sap is generally more or less acrid, purgative, emetic, or powerfully poisonous, from the presence of a principle dissipated by heat; starch abounds in the roots of some kinds, while oil of a purgative character is common in the seeds; the bark of some of the trees has tonic properties; the wood of several is very valuable for its hard, close texture; and several of the plants furnish dyes. The lactescent juice of *Siphonia elastica* is the source of the "bottle"

Caoutchouc of Brazil and Guiana; *Aleurites laccifera* yields Gum lac in Ceylon; *Euphorbia antiquorum* and *E. canariensis* are believed to yield the gum-resin called Euphorbium. The common Spurges (*Euphorbia*) have purgative properties; the root of *E. Ipecacuanha* is used as an emetic in North America; and the species of *Mercurialis* have similar properties, especially *M. perennis*, which is unsafe to use, since it produces violent purging, and even sometimes convulsions and death. The most deadly member of the Order seems to be the Manchineel (*Hippomane Mancinella*), a Panama plant, the juice of which is so acrid as to cause ulceration when dropped on the skin, and its apple-like fruit has a vesicating juice; the juice of *Excœcaria Agallochum* and *Hura crepitans* has similar properties.

The oily seeds are mostly purgative: Croton oil is expressed from those of *Croton Tiglium* and *Pavana* (East Indies); Castor-oil from those of *Ricinus communis*, in which the purgative property is found to reside in the embryo, not in the albumen; the seeds of *Hura crepitans* and *Curcas* (*Jatropha*) *purgans*, the "Purging-nut," are violent cathartics, and those of *Euphorbia Lathyris* are sometimes employed in the same way. The solid oil obtained from the seeds of *Stillingia sebifera*, the Tallow-tree, is used for making candles in China. Cascarilla bark, with tonic properties, is obtained from *Croton Eleuteria* (Bahamas); *C. pseuda-quina* and other species have similar qualities. *Oldfieldia africana* is the African Teak-tree. *Crozophora tinctoria* furnishes the dye called Turnsole; *Rottlera tinctoria* (East Indies) a scarlet dye.

The pure starch obtained by grating and washing the roots of *Jatropha Manihot* (*Manihot utilissima*) forms, under the name of Mandioc or Cassava, a most important article of food in South America; the finer particles of starch, softened by heat, and afterwards granulated, constitute Tapioca. The washing removes a narcotic poisonous matter which exists in the sap: the Indians dissipate this principle by heat, simply roasting the roots. It is a shrub about 8 feet high, with a large root, sometimes weighing 30 lbs., and is cultivated all over the tropics, but especially in America.

(BUXACEÆ constitute a very small Order, formerly included among Euphorbiaceæ, but differing in the absence of milky juice, in the loculicidal capsules, ovules pendulous from the inner angle of the cells of the ovary, micropyle superior and internal. The leaves of the common Box (*Buxus*) are purgative; the wood is specially used for engraving and for turners' purposes).

(DAPHNIPHYLLACEÆ are constituted by Müller, of Argau, a distinct group, differing from the two preceding in their small embryo, concealed in albumen).

(SCEPACEÆ are a small group of East-Indian plants, allied to Euphorbiaceæ, but having the flowers in catkins, thus forming a transition to the Cupuliferæ and Betulaceæ. Genera: *Scepa*, Lindl.; *Lepidostachys*, Wall.)

## ORDER CXXV. URTICACEÆ. THE NETTLE ORDER.

*Class.* Julifloræ, *Endl.* *All.* Urticales, *Lindl.* *Coh.* Urticales, *Benth. et Hook.*

484. *Diagnosis.*—Herbs, shrubs, or trees with stipules and monœcious or diœcious or, rarely, polygamous flowers; perianth regular, free from the 1-celled (rarely 2-celled) ovary; stamens equal in number to the lobes of the perianth, and opposite to them, or sometimes fewer, uncoiling elastically; embryo straight in the albumen when this is present, the radicle pointing upwards.

This Order is divided into the following tribes:—

1. UREREÆ. Leaves with stinging-hairs; leaves opposite, or if alternate arranged spirally; perianth of female flower 4-parted, rarely tubular, always free.
2. PROCRIDEÆ. Leaves without stinging-hairs; leaves opposite, or if alternate distichous; perianth of female flower free, 3–5-parted; stigma brush-like.
3. BŒHMERIEÆ. Plants without stinging-hairs; leaves alternate or opposite; perianth of female flower free or adnate to the ovary, frequently tubular, rarely very short.
4. PARIETARIEÆ. Plants without stinging-hairs; leaves alternate; flowers diœcious or polygamous; perianth of female flower tubular, free. Inflorescence bracteate.
5. FORSKÖHLIEÆ. Plants without hairs or with hardened hairs; leaves alternate or opposite; flowers diclinous, involucrate; perianth of female flower tubular or wanting.

### ILLUSTRATIVE GENERA.

UREREÆ.
- Urtica.
- Urera.

PROCRIDEÆ.
- Pilea.

BŒHMERIEÆ.
- Bœhmeria.

PARIETARIEÆ.
- Parietaria.

FORSKÖHLIEÆ.
- Forsköhlia.

**Affinities.**—This Order is nearly related to the Malvaceæ and Euphorbiaceæ on the one hand, and to the amentiferous Orders on the other; differing from the former in the simple ovary, from the latter in the usual presence of albumen in the seeds, and in the flowers not being arranged in catkins. There is a further relation to the Chenopodiaceæ, which, however, besides the circumstance that they are only occasionally diclinous, have the embryo curved round the outside of the albumen.

**Distribution.**—The *Urticeæ* are generally diffused, but are much more abundant in the intertropical regions than elsewhere.

**Qualities and Uses.**—Edible fruits and valuable fibres are the principal products of this Order.

*Bœhmeria* (*Urtica*) *nivea* furnishes the fibre for Chinese "Grass-cloth," or Ramee; *B. Puya* yields another valuable fibre; and the fibre of the Stinging-Nettle (*Urtica dioica*) was formerly used; *U. tenacissima* furnishes cordage in Sumatra.

(CANNABINACEÆ constitute a small group often included under Urticaceæ, but differing in their stamens not being elastic, their elongated, not rounded, anthers, and in their curved exalbuminous embryo (fig. 409). *Cannabis sativa* furnishes the hemp of commerce, which consists of the woody fibres of the plant separated by maceration. *C. indica* yields a narcotic resinous product known as Indian hemp. *Humulus Lupulus*, the Hop, is well known for its aromatic bitter properties.)

Fig. 409.

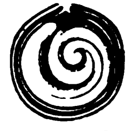


Fig. 409. Seed of *Humulus* opened.

## ORDER CXXVI. ARTOCARPACEÆ.

*Class.* Julifloræ, *Endl.* *All.* Urticales, *Lindl.* *Coh.* Urticales?, *Benth. et Hook.*

485. *Diagnosis.*—Trees or shrubs, or rarely herbs, with milky juice; leaves alternate, usually provided with convolute deciduous stipules; flowers diclinous, males in catkins, females in heads or flat receptacles; perianth 3–4-parted or none; stamens not elastic; ovary 1-celled; ovule solitary; albumen fleshy, or none; embryo straight or curved; radicle superior. Illustrative genera: *Artocarpus*, *Ficus*, *Morus*.

**Affinities.**—The main difference between this group and the Urticaceæ lies in the milky juice and general habit. The inflorescence and fruit of these plants are curious: in *Dorstenia* the flowers are imbedded in the top of a tabular fleshy peduncle (fig. 153); in *Ficus* enclosed in an excavated fleshy peduncle (fig. 152); in *Morus* the female flowers are developed in a sort of capitulum, and subsequently coalesce into a compound fleshy fruit, resembling a blackberry (fig. 306), but each "pip" is formed from a distinct ovary; in *Artocarpus* the numerous flowers are crowded on a globular fleshy peduncle, which enlarges into a large fleshy fruit, sometimes weighing 30 lbs. *Ficus indica* (the Banyan tree) is remarkable for sending down numerous roots from its branches, which strike into the earth and convert the tree into a kind of grove.

**Distribution.**—The Artocarpaceæ constitute a large group, whose members are almost exclusively tropical and subtropical.

**Qualities and Uses.**—Most of these plants have a milky juice, containing more or less of an acrid poisonous principle and of caoutchouc. *Broussonetia papyrifera* is the Paper-Mulberry tree, the inner bark of which is used for making paper &c. in China and the South-Sea Islands. *Antiaris saccidora* has a fibrous bark, used for cordage and matting, also *Cecropia peltata*, *Brosimum*, &c. Caoutchouc is largely obtained from *Ficus elastica* and other species; a milky juice, of very nutritious character, is obtained from the Cow-tree of South America, *Brosimum utile*.

The renowned Upas-tree of Java is a large tree, *Antiaris toxicaria*, which has a very poisonous juice, and it is stated that linen made from its fibres, if badly prepared, produces great irritation of the skin.

The fruit of *Maclura aurantiaca*, the Osage Orange, has an orange-coloured pulp, used by the North-American Indians to stain their skin; the wood of *M. tinctoria* is used by dyers under the name of Fustic. *Morus alba*, the White Mulberry, is largely cultivated in Italy and the East for feeding silkworms.

*Dorstenia Contrayerva* was formerly esteemed as a tonic and diaphoretic. The wood of *Ficus Sycomorus*, the Sycamore-fig, is very durable, and is supposed to have been used for mummy-cases. The seeds of the plants of this Order are generally wholesome and nutritious.

(STILAGINACEÆ constitute an Order of trees or shrubs, with alternate, simple, leathery leaves and deciduous stipules; flowers diclinous, spiked, with a single 2-, 3-, or 5-parted perianth; stamens 2 or more on a tumid receptacle; anthers 2-lobed, dehiscing at the apex; ovary free, 1–2-celled, each cell with a pair of suspended ovules; seed albuminous; embryo straight; radicle superior. These plants, natives of Madagascar and the East Indies, are nearly allied to *Urticeæ*, differing chiefly in the pulvinate disk, inelastic stamens, and anthers bursting at the apex. The drupaceous fruits of *Antidesma pubescens* and *Stilago Bunias* are subacid and agreeable.)

(PHYTOCRENACEÆ are an Order with somewhat obscure relations, consisting of a few East-Indian climbing shrubs with a curiously organized wood. They have diclinous flowers; but the rudiments of the abortive sexual organs exist in the flowers of both kinds, and the flowers have both calyx and corolla. They are sometimes included among the *Artocarpeæ*, but have seeds with abundant albumen. Genera: *Phytocrene*, Wall.; *Iodes*, Blume, &c.)

## ORDER CXXVII. ULMACEÆ. THE ELM ORDER.

*Class.* Julifloræ, *Endl.* *All.* Rhamnales, *Lindl.* *Coh.* Urticales, *Benth. et Hook.*

486. *Diagnosis.*—Trees with watery juice, alternate leaves, stipules, perfect or monœciously polygamous flowers; perianth free, membranous, campanulate or irregular (fig. 410); stamens definite; filaments straight or moderately incurved in the bud; ovary free, 1–2-celled; styles or stigmas 2; fruit a single samara (fig. 411) or a drupe; seed suspended, with little or no albumen; radicle superior.

Fig. 410.

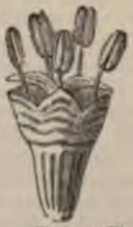


Fig. 411.

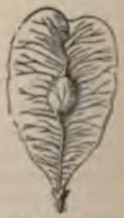


Fig. 410. Flower of *Ulmus*.
Fig. 411. Fruit of *Ulmus*.

ILLUSTRATIVE GENERA.

| Tribe 1. CELTEÆ. *Ovary* 1-*celled.* | Tribe 2. ULMEÆ. *Ovary* 2-*celled.* |
|---|---|
| Celtis, *Tournef.* | Planera, *Gmel.* |
| Mertensia, *H. B. K.* | Ulmus, *L.* |

**Affinities, &c.**—These plants, chiefly natives of northern countries, are very closely related to the *Artocarpeæ* and other Urticaceæ, scarcely distinguished by any general character except the polygamous structure of the flowers. They are timber-trees with bitter astringent bark; *Ulmus campestris* is the common Elm-tree, *U. montana* the Scotch or Wych Elm. *Celtis australis*, called the Nettle-tree, has a drupaceous fruit of astringent quality.

## ORDER CXXVIII. PLATANACEÆ. THE PLANE ORDER.

*Class.* Julifloræ, *Endl.* *All.* Urticales, *Lindl.* *Coh.* Urticales?, *Benth. et Hook.*

487. *Diagnosis.*—Trees with watery juice, alternate palmately lobed leaves, sheathing stipules, and monœcious flowers in separate and naked globular heads, destitute of calyx or corolla; the fruits consisting of heads of clavate 1-seeded nucules furnished with a bristly down along the base; seeds solitary, rarely 2, pendulous; embryo in very thin albumen; radicle inferior.

ILLUSTRATIVE GENUS.

Platanus, *L.*

**Affinities, &c.**—The Plane-trees, natives of North America and the Levant, naturalized in our parks and squares, are chiefly remarkable for the beauty of the form and foliage. The structure of the inflorescence is amentaceous as regards arrangement and the absence of envelopes; but the ovaries are like those of *Artocarpeæ*, from which they are divided chiefly by the achlamydeous flowers, the inferior radicle, and the presence of albumen in the seed.

## ORDER CXXIX. JUGLANDACEÆ. THE WALNUT ORDER.

*Class.* Terebinthinæ, *Endl.* *All.* Quernales, *Lindl.*

488. *Diagnosis.*—Trees with alternate pinnate leaves, without stipules; the sterile flowers in catkins, with an irregular perianth; the fertile solitary, or in small clusters, with a regular 3–5-lobed perianth adhering to the incompletely 2–4-celled ovary, with only 1 erect ovule. Fruit consisting of a dehiscent husk enclosing a woody shell, containing a large 2–4-lobed orthotropous exalbuminous seed; cotyledons oily, sinuous; radicle short, superior.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Juglans, *L.* | Carya, *Nutt.* |

**Affinities, &c.**—A small but well-marked group, nearly related to Cupuliferæ, but differing in the solitary ovule and in the absence of a cupule. From the resinous juices and pinnate leaves, they have been regarded as allied to Terebinthaceæ; but the latter have petals, a free ovary, and curved ovule. The Walnut (*Juglans regia*) is a well-known example of the Order. The wood of this, as well as of *J. nigra*, is valued by carpenters. The nuts of *J. cinerea* are called Butter-nuts in Canada. *Carya alba*, the Hickory of North America, has tough, elastic wood and an edible nut, as also has *C. olivæformis*.

## ORDER CXXX. CUPULIFERÆ. THE OAK ORDER.

*Class.* Julifloræ, *Endl.* *All.* Quernales, *Lindl.* *Coh.* Amentales, *Benth. et Hook.*

489. *Diagnosis.*—Trees or shrubs with alternate simple feather-veined leaves, and deciduous stipules; monœcious flowers, the barren in catkins or clustered, the fertile solitary or clustered and furnished with an involucre which forms a cup or covering to the flowers (fig. 413); ♂ stamens 5–20, inserted at the base of scales or of a membranous perianth; ♀ ovary crowned by the rudimentary teeth of an adherent calyx, 3- or more-celled (fig. 412); stigmas nearly sessile; ovules solitary, or 2 in a cell; fruit a 1-celled, woody nut, more or less enveloped by the involucre (cupule), containing 1 or 2 seeds (the rest being abortive), destitute of albumen; cotyledons large and fleshy; radicle minute, superior.

Fig. 412.

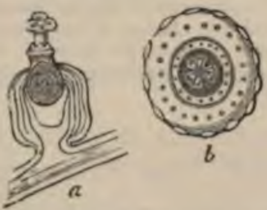


Fig. 413.

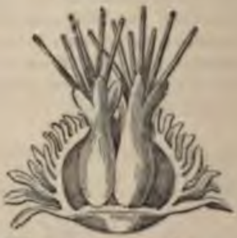


Fig. 412. *Quercus*: *a*, vertical section of female flower; *b*, cross section.
Fig. 413. Opened involucre, with two flowers of *Castanea*.

ILLUSTRATIVE GENERA.

Carpinus, *L.*
Corylus, *L.*
Fagus, *L.*
Castanea, *Gærtn.*
Quercus, *L.*
Ostrya, *Scop.*

**Affinities.**—Related to the Urticaceæ, but differing in the inferior, many-celled ovary and in the character of the fruits and seeds. From Betulaceæ and Salicaceæ, to which they are closely allied, they are separated by the inferior position of the ovary. Some authors separate the Corylaceæ from Cupuliferæ by reason of the achlamydeous male flowers and of the leafy cupule of the female flowers of the former.

**Distribution.**—A large group, the members of which are for the most part natives of forests of temperate climates.

**Qualities and Uses.**—Timber-trees of great importance; some also having edible fruits; the bark and other parts more or less astringent. *Quercus*, a very extensive genus, includes *Q. Robur*, British Oak, of which there are two varieties—*Q. sessiliflora*, Durmast, and *Q. pedunculata*. *Q. Suber* furnishes cork; *Q. Ægilops* has large rough cupules, extensively used by dyers under the name of Valonia; *Q. coccifera* is the Kermes Oak; *Q. tinctoria* furnishes Quercitron Bark; Nut-galls are produced by the attack of an insect on *Q. infectoria*; *Q. Ilex* is the Holm Oak, or Evergreen Oak of our shrubberies. Between 200 and 300 species of *Quercus* exist, some of which have edible fruits. *Corylus Avellana* is the Filbert, or Hazel; *Castanea vesca*, the Sweet Chestnut: *C. americana* produces a smaller nut; *Fagus sylvatica*, the common Beach, has a valuable hard wood, as also *Carpinus Betulus*, the Hornbeam; and *Ostrya virginica* is called Iron-wood in North America. Oil is obtained by pressure from the seeds of the Beech and the Hazel; the Nut-oil of the latter is largely used by painters.

(MYRICACEÆ constitute a small Order of shrubs with resinous-dotted often fragrant leaves; monœcious or diœcious achlamydeous flowers, both kinds in short scaly catkins; stamens 2-16; ovary 1-celled, with 1 erect ovule; fruit drupaceous; embryo without albumen; radicle superior. They differ from the other amentiferous Orders in the simple and free ovary; they are also related to Urticaceæ, but differ in the amentaceous inflorescence and in the structure of the seed. They have many points in common with Juglandaceæ, but differ in their achlamydeous flowers and superior ovary. They are aromatic shrubs or trees, with tonic and astringent properties; and wax, resin, and oil are obtained from them. *Myrica Gale*, the Bog-Myrtle, or Dutch Myrtle, yields an aromatic oil and secretes wax; *M. cerifera*, the Wax-Myrtle, secretes a green wax; *Comptonia aspleniifolia* is used in cases of diarrhœa in North America. The fruit of *Myrica sapida* is eaten in Nepal. Genera: *Myrica, Comptonia.*)

## ORDER CXXXI. BETULACEÆ. THE BIRCH ORDER.

*Class.* Julifloræ, *Endl.* *All.* Amentales, *Lindl.* *Coh.* Amentales, *Benth. et Hook.*

490. *Diagnosis.*—Trees or shrubs; monœcious, with both kinds of flowers in scaly catkins, 2 or 3 under each bract (scales of the flowers whorled in *Alnus*); ovary 2-celled, 2-ovuled, ripening into a dry, 1-celled, 1-seeded, often winged nut, without a cupule; seed pendulous, exalbuminous; radicle superior.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Betula, *L.* | Alnus, *L.* |

**Affinities, &c.**—This small Order is distinguished from Cupuliferæ and

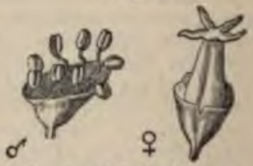
Juglandaceæ by the free ovary, and the regular occurrence of 2 carpels in the ovary, one cell, however, being usually obliterated in the fruit. From Salicaceæ they differ in the 2 cells, and by the solitary ovule in each cell. These plants belong chiefly to temperate and cold climates; *Betula nana* and *Alnus incana* form dwarf shrubs further north than any other woody plants, except some Willows. The bark is regarded as tonic and astringent, and an empyreumatic oil is obtained from that of the common Birches *Betula alba* and *glutinosa*, which gives the peculiar odour to Russia leather. The bark of *B. papyracea* is used for making baskets and many other articles in North America. The sap of *B. alba*, *nigra*, and *lenta* yields sugar at certain seasons. *Alnus glutinosa* is the common Alder; its wood is esteemed for work to remain under water, and for the manufacture of charcoal; the leaves and female catkins are sometimes used by dyers.

## ORDER CXXXII. SALICACEÆ. THE WILLOW ORDER.

*Class.* Julifloræ, *Endl.* *All.* Amentales, *Lindl.* *Coh.* Amentales, *Benth. et Hook.*

491. *Diagnosis.*—Diœcious trees or shrubs, with both kinds of flowers in catkins, one under each bract, entirely destitute of envelopes, or with a membranous cup-like perianth (fig. 414); the fruit a 1-celled and 2-valved pod, containing numerous seeds clothed with long silky down; no albumen; radicle inferior.

Fig. 414.



♂ male and ♀ female flower of *Populus*.

### ILLUSTRATIVE GENERA.

| Salix, *L.* | Populus, *L.* |
|---|---|

**Affinities, &c.**—This amentiferous Order, consisting of but two genera, one of which, *Salix*, is rich in species, is at once distinguishable by the 2-valved fruit having numerous seeds clothed with silky hairs. The 2-carpellary ovary and the inflorescence connect them closest with Betulaceæ. The Willows (*Salix*) and Poplars (*Populus*) belong to temperate and cold climates. Some are valuable for their timber; the young shoots of Willows furnish material for basket-work; and the bark has usually febrifuge properties, depending on the presence of Salicine. *Populus nigra* is the common Black Poplar, of which the Lombardy Poplar appears to be a fastigiate variety; *P. tremula* is the Aspen; *P. alba* is the Abele, or White Poplar. *Salix babylonica* is the Weeping Willow; Sallows and Osiers are the shoots from pollard stumps of *Salix viminalis*, *vitellina*, &c.; *Salix alba* is the ordinary Willow-tree found by river-sides. Willow-wood is used to some extent in turning, on account of its white colour, and it is esteemed for making charcoal.

## ORDER CXXXIII. CASUARINACEÆ.

*Class.* Julifloræ, *Endl.* *All.* Amentales, *Lindl.*

492. *Diagnosis.*—Pseudo-leafless trees with pendulous, jointed, striated branches, the nodes sometimes with short toothed sheaths (whorls of leaves); flowers in spikes, achlamydeous, diclinous; the barren flowers in loose spikes, with 2 bracts and 2 sepals, the latter adhering at their points; stamen 1; anther 2-celled; the fertile flowers in dense spikes or heads, with 2 bracts; ovary 1-celled, with 1–2 ascending ovules; seeds exalbuminous, with a superior radicle.

### ILLUSTRATIVE GENUS.

Casuarina, *L.*

**Affinities, &c.**—A small group consisting of trees of remarkable aspect, the branches having much the appearance of the branched *Equiseta.* The jointed stems and abortive leaves connect them also with *Ephedra* among the Gymnosperms, to which they approach also in the very reduced character of the flowers. They acquire large dimensions; and the wood of their trunks becomes very solid and heavy. The greater portion of them are natives of Australia, where they are called Beef-wood trees, from the red colour of the timber.

(CHLORANTHACEÆ constitute a small Order, having the following characteristics. Herbs or under-shrubs with jointed stems swollen at the nodes, opposite simple leaves with sheathing stalks and minute interpetiolar stipules; flowers in terminal spikes, achlamydeous, hermaphrodite or sometimes diclinous, with a scaly bract; stamen 1, or, if more, coherent and definite; ovary 1-celled, 1-seeded; seed pendulous; embryo in the apex of fleshy albumen; radicle inferior; cotyledons divaricate. Nearly related in general character to Piperaceæ, but differing from them and from Saururaceæ in the absence of the double endosperm, the embryo being without the "amniotic sac;" there is a more distant relationship to Urticaceæ, and perhaps some affinity to Loranthaceæ. The plants are tropical, commonly have fragrant properties; and the roots of *Chloranthus officinalis* and *brachystachys* are esteemed as tonic, febrifuge medicines in the West Indies. The species of *Hedyosmum* have similar properties. The leaves of *Chloranthus inconspicua* are occasionally used to flavour Tea.)

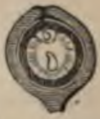
## ORDER CXXXIV. PIPERACEÆ. THE PEPPER ORDER.

*Class.* Piperitæ, *Endl.* *All.* Piperales, *Lindl.* *Coh.* Piperales, *Benth. et Hook.*

493. *Diagnosis.*—Shrubs or herbs with jointed stems; opposite, whorled, or, by suppression, alternate leaves; stipules absent, in pairs,

or singly opposed to the alternate leaves; flowers spiked, hermaphrodite or diœcious, achlamydeous, in the axil of a bract, with which they are sometimes confluent; stamens 2 or more; anthers 1–2-celled; ovary free, simple, 1-celled, with a single erect orthotropous ovule; fruit somewhat fleshy; seed erect, with the embryo in a distinct sac (*amnios*) at the top of copious albumen (fig. 415); radicle superior.

Fig. 415.



Section of seed of *Piper*.

### ILLUSTRATIVE GENERA.

Peperomia, *R. & P.*
Macropiper, *Miq.*
Chavica, *Miq.*
Cubeba, *Miq.*
Piper, *L.*
Artanthe, *Miq.*

**Affinities, &c.**—The stems of some of the Piperaceæ present so irregular a form of arrangement of the wood, that some authors have regarded them as belonging to the Monocotyledonous class; but this structure is not exactly that of the Monocotyledons, and they have a dicotyledonous embryo and reticulate-veined articulated leaves; they may, however, be regarded as connecting the two Classes through Araceæ, themselves somewhat anomalous forms of Monocotyledons. The chief peculiarity of the wood is the presence of woody bundles (sometimes forming a complete ring) in the pith. Their nearest relations are Chloranthaceæ and Saururaceæ; but they differ from the former in the sac of the embryo, the erect seed, and the alternate leaves; from the latter in the simple ovary and the absence of stipules. They are more distantly related to Urticaceæ.

**Distribution.**—A large Order, the species of which are for the most part tropical; most abundant in the hottest parts of America and of the East-Indian islands, in damp situations.

**Qualities and Uses.**—Pungent and aromatic, more or less astringent or narcotic. Black Pepper consists of the dried fruits of *Piper nigrum*; White Pepper is the same, with the fleshy epicarp removed by washing. Long Pepper consists of the dried spikes of *Chavica Roxburghii* (*Piper longum*); other species of *Chavica* are used in India and Tropical America, with *Artanthe adunca*, &c. The leaves of *Chavica Betle* are chewed, mixed with slices of the Betel Nut (*Areca oleracea*) and lime, by the Malays and other Indian races. The ripe fruits of *Cubeba officinalis*, *canina*, *Wallichii*, &c. form Cubebs, or Cubebs Pepper, and have aromatic, stimulant, and purgative properties; *Artanthe elongata* and *adunca* are said to have similar virtues. *Macropiper methysticum*, the Ava or Kava of the South-Sea Islands, has powerful narcotic properties. The leaves, or powdered leaves of *Artanthe elongata* are also esteemed as a styptic, known by the name of Matico, in South America (other plants are also called by this name, such as *Eupatorium glutinosum*). Most of the plants of this Order possess some of the above properties, more or less powerfully marked; *Artanthe crocata* yields a yellow dye, obtained from the spikes of fruit.

(SAURURACEÆ constitute a small group of aquatic or marsh plants, of North America, China, and North India, related to Piperaceæ, but differing in the compound ovaries and stipulate leaves and wood destitute of bundles in the pith. They are more or less acrid. *Saururus cernuus* is sometimes used in medicine, an irritating cataplasm being made from the root.)

(CERATOPHYLLACEÆ are aquatic herbs with whorled, finely dissected leaves, and minute axillary and sessile monœcious flowers, without floral envelopes, but with an 8–12-cleft involucre in place of a calyx; the fertile flower is merely a simple 1-celled ovary, with a suspended orthotropous ovule; the seed filled by a highly developed embryo with 2 cotyledons and a conspicuous plumule; radicle very short, inferior. The genus *Ceratophyllum*, of which some authors describe 6 species, while others reduce them to 1, constitutes this Order, consisting of aquatic plants with whorls of leaves, and having almost the appearance of some Confervoid. The relations of *Ceratophyllum* are obscure: it has been connected with the Haloragaceæ from its resemblance to *Myriophyllum*, while Lindley places it provisionally among his Urticales. The most remarkable point is the structure of the seed, which is exalbuminous, and consists principally of 2 fleshy cotyledons, inside which stand a decussating pair of leaves, and within these, surrounded by withered endosperm-cells, is the plumule, bearing a whorl of leaves separated by a short internode from the second pair. In the highly developed state of the plumule they resemble *Nelumbium*. They are found in ditches &c. throughout the northern hemisphere, and they have no active properties.)

(CALLITRICHACEÆ are small aquatic annuals, with opposite entire leaves, and solitary polygamous axillary flowers, without any proper floral envelopes; fruit 4-lobed, 4-celled, 4-seeded; seeds peltate; embryo inverted in the axis of fleshy albumen; radicle very long, superior. This Order consists of the genus *Callitriche*, comprehending the Starworts of our freshwater pools, of which 6 species occur in Europe and North America. Their flowers are so simple that it is difficult to settle their affinities. Some regard them as related to *Hippuris*, among the Haloragaceæ; but they appear to be truly achlamydeous, whence others consider them allied to Euphorbiaceæ, from which they differ only in their 4-lobed ovary and in the structure of the seed. They have no known properties.)

(PODOSTEMACEÆ are aquatics, growing on stones in fresh running water, with much the aspect of Seaweeds or Mosses; the minute flowers bursting from a spathe-like involucre; perianth 0 or of 3 sepals; stamens 1 or many, hypogynous; ovary compound, 2–3-celled, with 2–3 stigmas; ovules numerous; fruit a many-seeded, ribbed capsule, the placentation of which is axile or parietal; seeds exalbuminous, with a straight embryo. This is a group of very curious plants, having a distinctly Dicotyledonous embryo, but much the habit of the Monocotyledonous Naiadaceæ. Lindley regards them as related to Elatinaceæ, or possibly to Plantaginaceæ, by way of *Littorella*. *Hydrostachys* is diclinous, the other genera perfect. In some of the genera there is no real distinction between stem and leaf, the structure being analogous to a thallus. They are most numerous in South America; some occur in India; one in North America. They have no active properties; but some species of *Lacis* are used for food on the Rio Negro and other parts of South America.)

## ORDER CXXXV. BALANOPHORACEÆ.

*Class.* Rhizantheæ, *Endl.* *Class.* Rhizogens, *Lindl.* *Coh.* Rhizanthales, *Benth. et Hook.*

494. *Diagnosis.*—Root-parasites with amorphous fungoid stems, destitute of leaves, never green, with fleshy subterraneous rhizomes or tubers, and naked or scaly peduncles bearing spikes of flowers; flowers mostly unisexual; male flowers conspicuous, with a tubular entire, slit, or 3–5-lobed perianth, valvate in the bud; stamens usually 3–5, more or less connate, or distinct; female flowers very minute; perianth with the tube adherent, and mostly without a limb, or 2-lipped; ovary inferior, mostly 1-celled; styles 2; ovule solitary, pendulous; fruit a small, compressed, 1-seeded nut; seed with hard granular albumen and a lateral amorphous embryo.

### ILLUSTRATIVE GENERA.

Balanophora, *Forst.*
Cynomorium, *Michel.*
Sarcophyte, *Sparrm.*
Helosis, *Rich.*

**Affinities, &c.**—The peculiar parasitic habit and fungoid texture of the plants of this and the two succeeding Orders have induced many authors to separate them from all other Flowering plants as a distinct class; but the grounds of this separation seem untenable: parasitism occurs in plants of the most varied structure, and this character of habit is not even of ordinal value. The structure of the stems of Balanophoraceæ is merely a degraded form of the Dicotyledonous type; and the flowers are in like manner provided with all the real essentials of the Phanerogamous structure, since the acotyledonous embryos, upon which stress has been laid, occur in Orobanchaceæ, Orchidaceæ, and various other Orders. Dr. Hooker, who has most elaborately investigated this Order, regards them as having affinity, in their floral structures, to the Haloragaceæ, where, as in *Hippuris*, we find in plants not parasitic a reduction of the parts of the flowers as complete as that in *Cynomorium*. They are closely related to *Gunnera*; but differ in their parasitic habit, absence of leaves, &c.

Many of the plants seem to have styptic qualities; *Cynomorium coccineum* was formerly highly valued by surgeons for this purpose, under the name of *Fungus melitensis*. Some have very disagreeable odour, others are eaten like Mushrooms. They occur on the roots of various Dicotyledonous trees, chiefly on the mountains of tropical countries, especially the Andes and the Himalayas; a few occur at the Cape and other parts of Africa, and some in Australia. *Cynomorium* is found in Malta, North Africa, the Levant, and the Canary Islands.

(CYTINACEÆ are root-parasites of fungoid texture, with perfect or monœcious flowers, solitary and sessile or clustered at the end of a scaly stem; perianth 3–6-parted, anthers opening by slits; ovary inferior; ovules very numerous, growing over parietal placentas; fruit a 1-celled, many-seeded berry; seeds imbedded in pulp, albuminous or exalbuminous; embryo amorphous. *Cytinus hypocistis* (South Europe) is parasitic upon the roots of *Cistus*, and has unisexual flowers; *Hydnora*, a Cape plant, growing upon fleshy *Euphorbiæ* and other succulent plants, has hermaphrodite flowers. Except in habit, they have very little connexion with the Balanophoraceæ; and from Rafflesiaceæ they differ in the 3-merous structure of the perianth and the longitudinal dehiscence of the anthers. These plants are supposed by some writers to have a connexion with the Monocotyledons through Bromeliaceæ. *Cytinus* has astringent qualities; *Hydnora africana*, which has a putrid smell, is roasted and eaten by the African natives.)

## ORDER CXXXVI. RAFFLESIACEÆ.

*Class.* Rhizantheæ, *Endl.* *Class.* Rhizogens, *Lindl.* *Coh.* Rhizanthales, *Benth. et Hook.*

495. *Diagnosis.*—Parasites of fungoid structure, without stems or leaves; the flowers solitary, sessile upon the branches of trees, surrounded by scales, perfect or diœcious; perianth 5–10-parted, with a circle of scales or a ring in the throat; anthers 2-celled, and opening by distinct pores, upon a salver-shaped or subglobose column adhering to the perianth, numerous, distinct or connate, or concentrically many-celled with a common pore; ovules very numerous, growing all over the parietal placentas of the 1-celled ovary; fruit an indehiscent pericarp, with a great number of albuminous or exalbuminous seeds with an undivided embryo.

### ILLUSTRATIVE GENERA.

Rafflesia, *R. Br.* | Sapria, *Griff.* | Pilostyles, *Guill.*

**Affinities, &c.**—Some of the Rafflesiaceæ occur parasitic upon species of *Cissus* in the East Indies, others on Leguminous plants in South America. They differ from Cytinaceæ in the absence of a stem, the 5-merous perianth, and the porous anthers. They are sometimes regarded as related to the Aristolochiaceæ. *Rafflesia Arnoldi*, a plant of Sumatra, is a wonderful object, consisting of a gigantic flower of fungoid texture, measuring 3 feet across, and weighing 14 lbs., emitting in decay a smell like putrescent flesh. This and other species seem to have styptic and astringent properties.

## ORDER CXXXVII. ARISTOLOCHIACEÆ. THE BIRTHWORT ORDER.

*Class.* Serpentariæ, *Endl.* *All.* Asarales, *Lindl.*

496. *Diagnosis.* — Climbing shrubs or low herbs, with perfect, regular or irregular flowers; the conspicuous single tubular perianth (figs. 416, 417) (valvate in the bud) adherent below to the 6-celled ovary, which becomes a many-seeded 6-celled capsule or berry; stamens 6–12, more or less adherent to the style (fig. 418); anthers adnate, extrorse; ovules numerous; seeds albuminous; embryo minute.

Fig. 416.

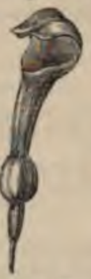


Fig. 417.

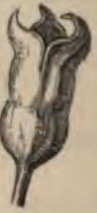


Fig. 418.

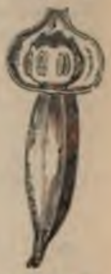


Fig. 416. Flower of *Aristolochia Clematitis.*
Fig. 417. Perianth of *Asarum.*
Fig. 418. Ovary and stamens of *Aristolochia.*

### ILLUSTRATIVE GENERA.

Asarum, *Tournef.* | Aristolochia, *Tournef.*

**Affinities.**—The ternary structure of the flowers of this Order, together with an aberrant structure of the wood, which presents no concentric rings, seems to indicate that these plants have affinities to such Monocotyledonous Orders as Dioscoreaceæ, although they are really Dicotyledonous. Their more immediate relationships are obscure; most authors connect them nearly with Nepenthaceæ, the affinities of which, again, are not clearly made out. Their stamens, adherent to the style, distinguish them from all other Monochlamydeous Orders.

**Distribution.**—A large Order, the species of which are generally diffused; most numerous in tropical South America.

**Qualities and Uses.**—Some of these plants have enjoyed considerable reputation, having pungent, aromatic, and stimulant qualities. The *Aristolochiæ* take their name from the roots of *A. Clematitis, longa, rotunda,* and others being used as emmenagogues. *A. Serpentaria,* Virginian Snake-root, is one of the many specifics for Snake-bites, and it is stomachic and tonic. It is worth notice that several species of *Aristolochia* in different countries are considered by the natives valuable remedies in cases of snake-bite. *Asarum europæum,* Asarabacca, is acrid; its leaves were formerly much used in a snuff employed in affections of the eyes. Some of these plants are very handsome climbers, with large cordate leaves, and striking helmet-shaped flowers. Those of *Aristolochia cordata* are large enough to be used as caps by the Indian boys in the Brazilian woods. The West-African *A. Goldieana* is equally large.

(NEPENTHACEÆ are herbs or half-shrubby plants with alternate leaves which, when perfect, have a long stalk terminating in a pitcher with an articulated lid (fig. 104); flowers diœcious; perianth 4-merous; stamens coherent in a solid column; anthers about 16, extrorse; ovary free, 4-angled, 4-celled; seeds very numerous, attached to the sides of the dissepiments; embryo in fleshy albumen. The relations of this Order are at present obscure; most authors connect them with the Aristolochiaceæ &c. They are natives of swamps in the East Indies and China, and one or two are found in the Seychelles and Madagascar. Several species are cultivated in our stoves on account of the curious pitcher-like organs which are developed from some of their leaves (§ 101). They do not appear to have any active properties.)

## Class II. MONOCOTYLEDONES.

497. Angiospermous Flowering Plants, with stems in which the woody bundles are isolated and diffused through a parenchyma in which there is no distinction of pith and bark, the individual woody bundles never being developed further after the fall of the leaves to which they belong; the leaves (very commonly sheathing at the base) generally with a number of nearly parallel, straight or curved ribs (fig. 419), or with similar ribs given off from a midrib (fig. 420); the cross veins suddenly smaller (fig. 421), occasionally netted-veined: the flowers generally with three organs in each whorl

Fig. 419.

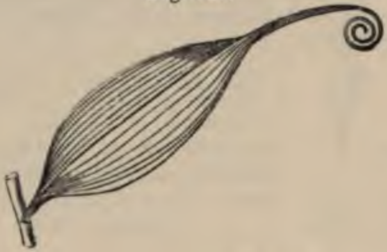


Fig. 422.

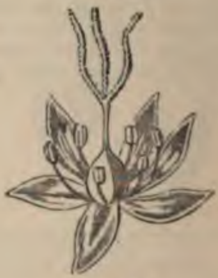


Fig. 420.

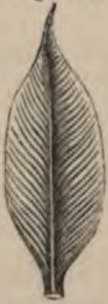


Fig. 421.

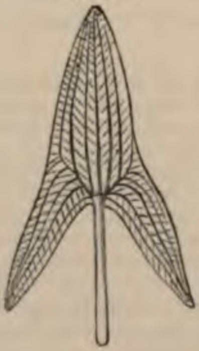


Fig. 423.

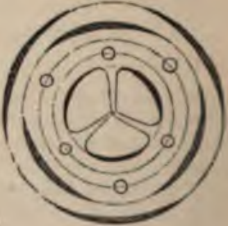


Fig. 424.

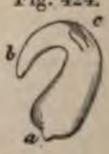


Fig. 419. Leaf of *Gloriosa*.
Fig. 420. Leaf of *Canna*.
Fig. 421. Leaf of *Sagittaria*.
Fig. 422. Ternary flower of *Luzula*.
Fig. 423. Diagram of ditto.
Fig. 424. Monocotyledonous embryo of *Potamogeton*.

(figs. 422, 423); the floral envelopes often all petaloid or all green or scale-like, rarely with a green calyx and coloured corolla; seed with an embryo which possesses only one cotyledon, usually rolled round the plumule like a sheath (fig. 424, *b*, *c*); the radicle (*a*) never developed into a tap-root in germination.

## SUBCLASS 1. SPADICIFLORÆ.

498. Monocotyledons with the inflorescence composed of flowers with a scaly, incomplete perianth, or achlamydeous, often unisexual, arranged on a more or less fleshy spadix, which is naked, or more frequently enclosed by a large spathe.

In the Palmaceæ, the structure of the flowers approaches that of Liliaceæ in the next Subclass; the Lemnaceæ, usually considered the lowest representatives of the Aroid type, have so few flowers that the spadiciform peduncle does not represent this structure very clearly; but it is surrounded by a spathe. Taccaceæ resemble Araceæ in habit (but their flowers are far more complete); hence they connect this Subclass with the next.

## ORDER CXXXVIII. PALMACEÆ. PALMS.

*Class.* Principes, *Endl.* *All.* Palmales, *Lindl.* *Coh.* Palmales, *Benth. et Hook.*

499. *Diagnosis.*—Trees or shrubs, mostly with a simple unbranched trunk (fig. 425), occasionally slightly ramified, with large terminal clusters of mostly compound, stalked leaves, the stalks sheathing at the base; flowers unisexual or perfect, with a double 3-merous perianth, on a mostly branched, scaly spadix enclosed by spathe (fig. 426); stamens 6, hypogynous or perigynous; ovary of 1–3 free or coherent carpels; ovules solitary, rarely two; fruit baccate; seeds with a minute embryo imbedded superficially in horny, fleshy, or bony albumen (fig. 428).

### ILLUSTRATIVE GENERA.

Chamædorea, *Willd.*
Areca, *L.*
Ceroxylon, *H. & B.*
Caryota, *L.*
Calamus, *L.*

Sagus, *Gærtn.*
Borassus, *L.*
Lodoicea, *Labill.*
Sabal, *Adans.*
Chamærops, *L.*

Rhapis, *L. fil.*
Phœnix, *L.*
Attalea, *H. B. K.*
Elais, *Jacq.*
Cocos, *L.*

**Affinities, &c.**—The Palms form a very natural Order, including a great number of plants varying to a considerable extent among themselves, but separated by very distinct characters from the rest of the Monocotyledons. They, as a rule, assume an arborescent character, the stem being formed on the same fundamental plan as those occasionally occurring in other Orders of Monocotyledons; the stem of the Calamoid Palms bears much resemblance to that of the Bamboo among the Grasses;

Fig. 428.

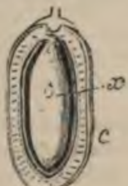


Fig. 427.

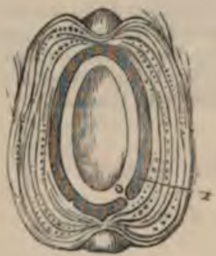


Fig. 425.

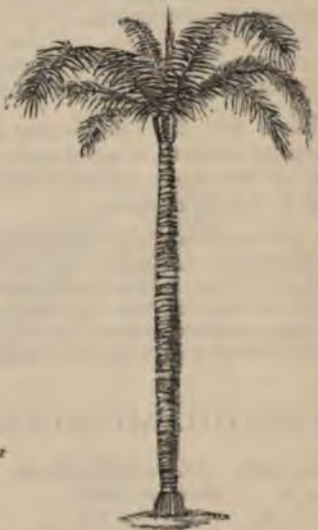


Fig. 426.

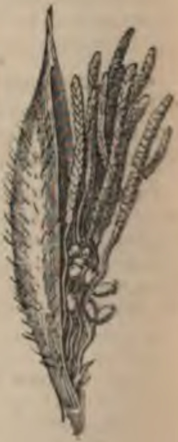


Fig. 425. Trunk and foliage of a species of *Areca*.
Fig. 426. Spathe and spadix of *Astrocaryum vulgare*.
Fig. 427. Section of the fruit of the Cocoa-nut Palm: *x*, the shell of the nut.
Fig. 428. A Date, with half the pericarp (*c*) removed to show the seed and embryo (*x*).

the forms with scarcely developed internodes, marked externally by the scars of the fallen leaves, agree essentially with those of *Yucca*, *Xanthorrhœa*, &c., except that the fibrous cortical region is little developed, and does not exhibit growth by successive layers as in those plants; the *Hyphœnes*, which have a branched stem, seem to ramify in the same way as the *Vellosieæ*, by a bifurcation resulting from the occasional development of an axillary bud, which manifests a power of growth equal, or nearly so, to that of the terminal bud. The ramification of the trunks above ground is a rare phenomenon; but it is very common for suckers to be sent out from the bases of the stems below the soil, imitating on a large scale the appearance of the young bulbs around the parent in the herbaceous Monocotyledons. The parenchymatous substance of the stem, in which the fibrous structures are imbedded, varies much in consistence: sometimes it becomes lignified, and gives a solid character to the trunk, as in the Cocoa-nut Palm; sometimes it is soft and spongy internally, as in the Sago-palms, becoming filled at certain seasons with starch. The spadiciform inflorescence, unfolding from within a large foliaceous spathe, connects the Palms with the Araceæ, a relationship further indicated by the low type of structure of the floral envelopes; but there is a general tendency to union of the sexes here, and a difference in the position of the embryo within the albumen,—not to dwell upon the wide diversity of general structure and habit. The regular ternary arrangement of the flowers, the 6 stamens, and the 3-carpellary superior ovary approximate this family to the Liliaceæ, in which, however, the habit differs in almost every respect, besides the great diversity of the fruits and seeds. The inflorescence of the Palms is in some cases axillary, allowing of indefinite growth of the trunk by the terminal bud; in other cases it is terminal, and the flowering of the plant then puts a period to the term of growth (sometimes as much as 20 years), the trunk dying after the ripening of the fruit (like the main stem of the *Agave*), but occasionally perpetuating itself by subterranean axillary suckers. Sometimes the axillary inflorescence breaks out from above the cicatrix of a long-fallen leaf, on the bare part of the stem. The flowers are generally very numerous; it is said that the male inflorescence of the Date bears 12,000 flowers, and that a bunch of some of the South-American Palms will bear 3000 fruits. In *Alfonsia amygdalina* 207,000 flowers have been computed on a single spadix, or 600,000 on one plant! There is very considerable apparent variety of form and structure of the ripe fruit in this Order, easily reducible, however, to a single type. As a rule, there are 3 carpels, either distinct or united into a 3-celled ovary, each carpel commonly producing 1 ovule; in *Cocos*, however, 2 out of the 3 cells are rudimentary, and thus only 1 ovule is developed even at first; in *Areca* and others, 3 distinct cells and ovules originally exist; in *Chamærops* and *Phœnix* the 3 carpels form separate 1-ovuled pistils; in *Borassus*, a 3-celled, 3-ovuled ovary exists, and the same in *Lodoicea*. In the course of the maturation of the fruit, the pericarp becomes variously developed, and more or less of the ovules or of the distinct simple ovaries are aborted. In *Cocos* the pericarp is developed around the one perfect cell, externally as fibrous husk, internally as the woody shell of the nut; the fleshy part of the nut (hollow) constitutes the albumen of the seed surrounded by a brown testa; and the embryo is lodged in a cavity in the substance of the albumen, at one side, near the base (fig. 427). In *Areca*, 2 out of the 3 cells and ovules are abortive: the pericarp ripens into a fibrous husk round a solid seed, chiefly composed of horny ruminated albumen (the Areca-nut). In *Chamærops* and *Phœnix*, 1 out of the 3 simple ovaries ripens into a berry; the pericarp, becoming the pulp (Date), contains a "stone," or seed which is a solid mass of horny albumen with the embryo imbedded in a small cavity a little beneath the surface (fig. 428), its place being indicated by a papilla on the surface. In *Borassus*, all the ovules become developed, and form 3 fibrous "stones" in the fruit. In *Lodoicea* it often happens that 2 or even 3 ovules coalesce during ripening, forming large, hollow, double or triple nuts, of the same character as the Cocoa-nut, enclosed in a large fibrous husk (these are the "Double Cocoa-nuts" of the Seychelles Islands). In *Sagus* and other genera the ovary is clothed with imbricated scales pointing to the base, which ripen into woody structures, forming a peculiar hard-scaled covering to the fruit.

**Distribution.**—A large Order, consisting of about a thousand species, chiefly tropical; scarce as regards species in Africa; a few advancing into temperate latitudes in North America, Europe and Asia, and New Zealand.

**Qualities and Uses.**—Having (apparently) no noxious properties, the very varied products of this noble Order of plants render them of an importance to man second, perhaps, only to that of the Cereal Grasses. Their juices and secretions furnish sugar, starch, oil, wax, and resins; fermentation of the juices of many produces spirituous liquids. Some have edible fruits of great importance; the succulent buds of others are used as esculent vegetables; their leaves are applicable to countless uses, from thatching huts to plaiting mats and hats; the fibrous substance of the sheathing petioles furnishes material for cordage, or, when more solid, supplies a valuable substitute for bristles and whalebone; the fibrous husks of the fruits afford textile materials; the trunks of some kinds become valuable timber; and the hard albumen of the seeds of several kinds is very largely used for turners' work connected with cabinet-making &c.

Saccharine juice, furnishing sugar or fermented liquid, according to the use made of it, is obtained abundantly by cutting the unopened spathes of *Caryota urens*, *Cocos nucifera*, *Borassus flabelliformis*, *Rhapis vinifera*, *Saguerus* (*Arenga*) *saccharifer*, *Phœnix sylvestris*, *Mauritia vinifera*, *Elais guineensis*, and others; starch is obtained abundantly from the central parenchyma of the trunk of *Sagus Rumphii*, *Metroxylon læve*, *Saguerus saccharifer*, *Phœnix farinifera*, &c. Oil is obtained especially from the African Oil-Palms (*Elais guineensis* and *E. melanococca*), the fruits being crushed and the oil extracted from the albumen by boiling in water; Cocoa-nut oil is obtained from the albumen of the seed; wax is excreted on the lower surface of the leaves of *Copernicia cerifera*, on the trunk and between the leaves of *Ceroxylon andicola*. *Calamus Draco*, *Hyphæne*, and others have a resinous matter in their juices. The most important fruits are those of the Date (*Phœnix dactylifera*) and the Cocoa-nut (*Cocos nucifera*); the fruit of *Hyphæne thebaica*, the Egyptian Doum-palm, is also eaten; and the seeds of *Areca Catechu* (Betel-nuts), are very largely used in the East Indies, for chewing with the leaves of the Betel Pepper. The fruits of some of the Palms are acrid (*Caryota*, *Saguerus*); the acridity, however, is removed by soaking in lime-water, and they are eaten preserved with sugar. The Indian Cabbage-palm, of which the buds are eaten boiled like cabbages, is *Areca oleracea*; *Euterpe montana* is used in the same way. Fibrous substance is derived from the husk of the fruit of the Cocoa-nut (Coir), *Astrocaryum vulgare*, *Attalea funifera*, and others; the bristle-like Piassaba fibres, used for brooms, are from *Leopoldinia Piassaba*. The wood of the Cocoa-nut Palms is hard, durable, and handsome (Porcupine-wood); *Borassus flabelliformis* yields what is called Palmyra-wood. Nuts suitable for turning are afforded by the seeds of *Attalea funifera* (Coquilla nuts) and *Phytelephas macrocarpa* (Vegetable Ivory).

Common canes are the stems of *Calamus Scipionum*, *Zalacca*, *Rudentum*, &c. Partridge canes, used for walking-sticks &c., are stems of an unknown Palm. The petioles of *Chamærops humilis* are used for walking-canes in Italy; and the fibre of the leaves of this plant is now coming extensively into use as a substitute for horse-hair. The foregoing is only a brief summary of some of the best-known uses of these plants; similar products and applications are connected with a great number of other species besides those here mentioned. Several species are cultivated, for the grandeur of their foliage, in our stoves; and some, such as *Jubæa spectabilis*, *Chamærops excelsa*, are sufficiently hardy to be grown out of doors in the south of England.

## ORDER CXXXIX. PANDANACEÆ. SCREW-PINES.

*Class.* Spadicifloræ, *Endl.* *All.* Arales, *Lindl.*

500. *Diagnosis.*—Trees or shrubs of Palm-like habit, but often dichotomously branched, with the leaves sheathing at the base, imbricated in 3 spiral ranks; flowers numerous, naked or scaly, male and female or polygamous, arranged densely on a spadix furnished with numerous spathaceous bracts; anthers stalked, 2–4-celled; ovaries mostly grouped, 1-celled, with solitary or numerous ovules on parietal placentas; fruits with a fibrous husk, 1-seeded, arranged in groups, or many-celled berries with many-seeded cells; embryo minute, imbedded at the side near the base of fleshy albumen.

ILLUSTRATIVE GENERA.

Suborder 1. PANDANEÆ. *Flowers naked; leaves simple.*
Pandanus, *L. fil.*
Freycinetia, *Gaud.*

Subord. 2. CYCLANTHEÆ. *Flowers mostly with a perianth; leaves fan-shaped or pinnate.*
Carludovica, *R. & P.*
Nipa, *Rumph.*
Cyclanthus, *Poit.*

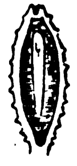
**Affinities.**—This Order is related on the one hand to the Typhaceæ by the inflorescence, which resembles that of *Sparganium*; on the other to the Palmaceæ, which the *Cyclantheæ* approach in habit and foliage. The branching stem and the large aërial roots of *Pandanus* (fig. 9) are exceedingly curious.

**Distribution.**—Tropical: the *Pandaneæ* chiefly in the East-Indian Islands, Mauritius, &c.; the *Cyclantheæ* American.

**Qualities and Uses.**—The seeds edible; saccharine fermentible juice flows from the cut spadices of *Nipa* and other species; the leaves and fibres are used for cordage, plaiting hats, &c.

(TYPHACEÆ are marsh-herbs, with nerved and linear sessile leaves and monœcious flowers, on a spadix or in heads, destitute of a proper perianth, which is replaced by 3 or more scales or a tuft of hairs; stamens 1–6, distinct or monadelphous; anthers innate; ovary solitary, 1-celled; ovule solitary, pendulous; embryo in the axis of mealy albumen (fig. 429); radicle next the hilum. The habit and general appearance of these plants resemble those of Cyperaceæ, and the hairs of the flowers of *Typha* are analogous to those of *Eriophorum*; but they belong to the Araceous type, and the structure of their inflorescence approaches closely, in *Sparganium* especially, to that of Pandanaceæ, which, however, have the ripe fruits more or less blended into a mass. There is also some resemblance in the inflorescence and in the flowers to Platanaceæ. The plants grow in ditches and marshes in most parts of the world. The rhizomes of *Typha* contain a certain amount of starch, and the young shoots of Bulrushes (*T. latifolia* and *T. angustifolia*) are sometimes used as esculent vegetables, like those of Asparagus. The abundant pollen is also nutritious, and is made into a kind of bread in Scinde, in New Zealand, and elsewhere.)

Fig. 429.



Section of seed of *Typha*.

## ORDER CXL. AROIDEÆ.

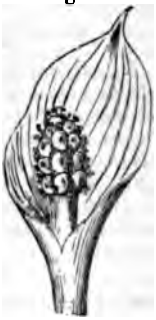


Fig. 430.

Inflorescence of *Calla*.

*Class.* Spadicifloræ, *Endl.* *All.* Arales and Juncales, *Lindl.* *Coh.* Arales, *Benth. et Hook.*

501. *Diagnosis.*—Plants with acrid or pungent juice, simple or compound (often veiny) leaves, and monœcious or perfect flowers crowded on a spadix, which is usually surrounded by a large bract or spathe (fig. 430); perianth wanting, or of 4–6 scales; fruit usually a berry; seed with the embryo in the axis of mealy or fleshy albumen, or occasionally exalbuminous.

### ILLUSTRATIVE GENERA.

Subord. 1. ARACEÆ. *Flowers imperfect; spadix surrounded by a spathe.*

Arum, *L.*
Colocasia, *Ray.*
Caladium, *Vent.*
Dieffenbachia, *Schott.*
Richardia, *Kunth.*

Subord. 2. ORONTIACEÆ. *Flowers perfect, mostly with a perianth; spadix surrounded by a spathe, or naked.*

Tribe 1. *With a spathe.*
  Calla, *L.*
  Pothos, *L.*
Tribe 2. *Without a spathe.*
  Orontium, *L.*
  Acorus, *L.*

**Affinities.**—The peculiar thickened fleshy flowering stem densely covered with flowers of rudimentary structure, forming the *spadix* of this Order, together with the spathe met with in most cases, give the group a character of habit which is generally very distinct; some genera, however, such as *Acorus*, depart from this form, and approach the Typhaceæ or Cyperaceæ in aspect, with which the spadicifiorous structure at the same time unites them; they have further relations with the Pandanaceæ, and also with the Palmaceæ, in which the inflorescence shares the spadicifiorous characters; and although the perianth is much more definite and highly developed there, its presence in *Acorus* and *Orontium* of this Order forms a connecting link. Lemnaceæ are closely related here, and perhaps should be regarded as the simplest form of Aroids; but the conditions are so simple there that it is more convenient to separate them. From Naiadaceæ, in which the inflorescence is moreover hardly spadicifiorous, the Aroids are easily distinguished by the character of their seeds. The Araceæ are either herbs, sometimes with very large leaves and spathes, or their stem becomes more or less developed and branched, so as to give them a shrubby character; while others are epiphytic and climbing plants, producing aërial roots like the Orchids. The leaves are of the most varied character in this Order.

**Distribution.**—A large Order, not numerous in temperate climates, but represented there by *Arum*, *Calla*, and *Acorus*. Most abundant in the tropics, especially in forests and the lower regions of mountains.

**Qualities and Uses.**—The juices of the Aroids are generally acrid and dangerous, some very poisonous; but heat seems to dissipate the noxious principles. The acridity is replaced by agreeable aromatic pungency in *Acorus Calamus*. The corms and rhizomes often contain much starch, which is extracted, and purified by washing, from *Arum maculatum* (Portland Arrow-root); while the corms of *Arum indicum*, *Amorphophallus campanulatus*, *Caladium bicolor*, *Colocasia esculenta* ("Cocoes" and "Eddoes," West Indies), *C. macrorhiza* ("Tara," South-Sea Islands), and *C. himalayensis* are eaten, roasted or boiled. The rhizomes of *Calla palustris* are also eaten after thorough washing. *Dieffenbachia seguina*, the "Dumbcane" of the West Indies, is so called from the inflammation of the tongue and fauces produced by chewing it; *Dracontium pertusum* (remarkable for its perforated leaves) has blistering properties. *Symplocarpus fœtidus*, the "Skunk-cabbage" of North America, is very fœtid, as is also the newly opened inflorescence of *Arum Dracunculus*, *A. italicum*, and others, which produce sickness and serious indisposition in some constitutions. *Richardia africana* is the white-spathed "Trumpet-lily" of our conservatories. The species of *Philodendron*, with rosy spathes and broad leaves 2 feet and more long, are very handsome stove-plants. The recently introduced *Anthurium Scherzerianum* is particularly noticeable for its brilliant scarlet spathes and its twisted spadix.

(LEMNACEÆ are minute stemless plants, floating free on the water, either destitute of distinct stem and foliage, as in *Lemna*, or consisting of tufts of leaves connected by filiform runners (*Pistia*); producing few monœcious flowers, surrounded by a spathe, from a chink at the edge or upper surface of the frond, or in the axils of the leaves; stamens definite, sometimes monadelphous; ovary 1-celled, with 1 or more erect ovules from the base of the cell; fruit a 1- or more-seeded utricle; embryo straight, in the axis of fleshy albumen. *Lemna*, the genus to which the common Duckweeds belong, is one of the simplest representatives of the Phanerogamia, composed of a stem consisting of 2 or 3 small leaf-like lobes producing little filiform roots below, and ultimately displaying a scale-like spathe at the margin, enclosing the inflorescence, reduced to two naked and unisexual flowers; the male flower consisting of one or two stamens, the female of a simple pistil. *Pistia*, also represented by little floating water-plants, has distinct tufted leaves, and the tufts are connected by flagelliform branches like the runners of a Strawberry. The spathes are here axillary, and they enclose separate male and female flowers seated on distinct parts of the central line of the spathe, which would appear therefore to be a branch, like the leafy peduncle of *Ruscus*, or else it has the spadix or peduncle adherent to its inner face. By some this genus, with *Ambrosinia*, is included under true Arads. The Lemnaceæ are the lowest forms of the Aroid type of Monocotyledons, and are related by habit to the Naiadaceæ. The *Lemnæ* occur chiefly in cool climates; *Pistia* principally in the tropics. *Pistia* appears to possess acrid properties; but the plants are of little importance, except, perhaps, as tending to purify the stagnant pools and ditches in which they abound. Genera: *Lemna*, L.; *Pistia*, L.; *Ambrosinia*, L.)

## SUBCLASS 2. PETALOIDEÆ.

502. Monocotyledons, with the floral envelopes consisting of a regular or irregular perianth, of two whorls, both petaloid, or more rarely both herbaceous, sometimes with a green or scaly calyx and a petaloid corolla; the flowers mostly perfect, more rarely unisexual; the leaves with the primary ribs parallel, or with a midrib and parallel secondary ribs, or rarely reticulated somewhat in the same manner as Dicotyledons, but with the veins branching at more obtuse angles.

The greater part of the Orders here associated have a natural connexion in the structure of the perianth (either superior or inferior), the syncarpous ovaries, and the albuminous seeds. But a small assemblage of Orders which are included here diverge greatly from the general character, while they differ so much from each other that they cannot very well be separated in the form of one distinct group: these are the Hydrocharidaceæ, the Alismaceæ, and the Naiadaceæ, which agree in the common character of an exalbuminous seed: but the first have an inferior compound ovary, and seem to approach Bromeliaceæ; the second have more or less distinct carpels, together with a green calyx and coloured corolla, such as occurs in Commelynaceæ; while the third, also apocarpous, in their simpler forms approach in habit to the Araceæ.

### *Section* A. Ovary inferior.

(TACCACEÆ are tropical perennial herbaceous plants with tuberous roots and large leaves, somewhat resembling Araceæ in habit, but with epigynous, petaloid, hermaphrodite flowers, the perianth of which is tubular; concealing 6 stamens with petaloid filaments incurved and hooded at the apex; ovary 1-celled, with 3 parietal placentas projecting more or less into the interior; fruit a berry; seeds with fleshy albumen. The plants are commonly regarded as connecting the epigynous Monocotyledons with the Aristolochiaceæ, a Dicotyledonous Order with 3-merous flowers; they have affinity in habit to the Araceæ, and in the flowers approach Bromeliaceæ. The watery juices of these plants are acrid: but the tuberous roots contain much starch. This is extracted by washing from *Tacca pinnatifida*, by the inhabitants of Tahiti and other islands of the South Sea, who use the meal for bread, cultivating the plant in fields. This species, with *T. dubia*, *montana*, and others, are used in like manner in Malacca, the Moluccas, Cochin China, &c., and are sometimes eaten raw with an acid, which neutralizes the acridity. Genera: *Tacca*, Forst.; *Ataccia*, Presl.)

### ORDER CXLI. DIOSCOREACEÆ. YAMS.

*Class.* Artorhizæ, *Endl.* *Class.* Dictyogens, *Lindl.* *Coh.* Iridales, *Benth. et Hook.*

*503. Diagnosis.*—Plants with twining stems rising from large tuberous or knotted woody root-stocks, with broad netted-veined stalked leaves, small diœcious 6-androus regular flowers, the tube of the 6-parted perianth adhering in the fertile flowers to the 3-celled ovary; styles 3, distinct or deeply trifid; ovaries 1–2 in a cell: stamens of the barren flower 6, on the perianth; fruit a 3-celled (or by suppression 1-celled) dehiscent capsule, or a succulent berry; seeds with a small embryo in a cavity in the hard albumen.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Tamus, *L.* | Dioscorea, *L.* |

**Affinities.**—Very near to Smilaceæ, from which they differ in the inferior ovary and the cavity in the albumen; the mostly capsular fruit is replaced by a berry in *Tamus*, like that of *Smilax*, but inferior instead of superior. The epigynous condition relates these plants to Amaryllidaceæ. Some authors consider that they are related to Aristolochiaceæ; but it is a distant affinity.

**Distribution.**—A rather large group, chiefly tropical; *Tamus communis* is British.

**Qualities and Uses.**—The sap is often more or less acrid; but the tubers formed by certain species of Yams, *Dioscorea sativa*, *alata*, and *aculeata*, contain abundance of starch; so that, under cultivation, and after cooking, when the noxious principle is dissipated, they become valuable articles of food. The tubers of other *Dioscoreæ* are unfit for food; and those of *Tamus communis*, Black Bryony, have acrid, purgative, and emetic properties. *Testudinaria elephantipes*, a Cape plant, in cultivation in our Botanic Gardens, produces a remarkable tuber above ground, resembling a rugged stump of an old tree, covered by a kind of false bark, which is tessellated with large compound angular facets; its internal substance is eaten by the Hottentots.

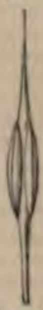
(PHILESIACEÆ are climbing or erect shrubs with coriaceous, netted-ribbed leaves and large and showy perfect flowers with an 6-merous perianth in two circles, equal, or the calyx much shorter: stamens 6, adherent to the perianth at the base; ovary 1-celled, with 3 parietal placentas; ovules semianatropous (not orthotropous, as is commonly stated). These plants, consisting of *Lapageria rosea*, a climbing shrub with beautiful crimson flowers, and *Philesia buxifolia*, the flowers of which differ chiefly in the marked difference of calycine and corolline circles and the mode of union of the bases of the filaments, differ from Liliaceæ chiefly in the parietal position of the placentas: in habit *Lapageria* is related to *Smilax*, and is in some measure intermediate between Smilaceæ and Liliaceæ. They are Chilian plants, now in cultivation with us. *Lapageria* bears sweet edible berries.)

(ROXBURGHIACEÆ consist of 4 species of *Roxburghia*, twining shrubs with broad leathery leaves and tuberous roots, from the hotter parts of the East Indies. Their habit connects them with Smilaceæ; but their perianth is composed of 4 petaloid pieces, and they have 4 stamens with enlarged connectives (each set of organs, according to Griffith, in 2 dimerous circles), and the 1-celled ovary (formed of 1 carpel, according to Griffith) has numerous anatropous ovules arising from the base of the cavity; the sessile stigma is penicillate. The fruit is 2-valved, with 2 clusters of seeds attached on long cords; embryo in the axis of fleshy albumen. The affinities of these plants are not clear; but the resemblance is perhaps greater to *Paris* than any other genus that can be named.)

## ORDER CXLII. SMILACEÆ. THE SARSAPARILLA ORDER.

*Class.* Coronarieæ, *Endl.* *Class.* Dictyogens, *Lindl.* *Coh.* Liliales, *Benth. et Hook.*

Fig. 431.



Stamen of *Paris*.

504. *Diagnosis.*—Herbs or climbing shrubby plants with stalked netted-veined leaves, regular perfect or diœcious flowers, with the 6–10-parted perianth of the fertile flowers free from the 3–5- (rarely 1–2-)celled ovary; stamens 6–10, introrse; styles or sessile stigmas as many as the cells of the ovary, and distinct; fruit a berry with few or several seeds; embryo minute, in hard fleshy albumen.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Smilax, *L.* | Trillium, *Mill.* |
| Paris, *L.* | Medeola, *Gronov.* |

**Affinities.**—The plants are not separated by any good characters from the Asparageous tribe of the Liliaceæ on the one hand, while they pass into Dioscoreaceæ on the other, from which they differ chiefly in having a superior ovary. *Smilax* represents Smilaceæ proper; *Paris*, *Trillium*, &c. have the calyx unlike the corolla, and are sometimes made a separate Order, called Trilliaceæ.

**Distribution.**—A considerable Order in point of numbers. Temperate parts of Europe, Asia, and America. Many species of *Smilax* in tropical America and Asia.

**Qualities and Uses.**—*Smilax* has diuretic and demulcent properties, for which the creeping rhizomes of many species are used, under the name of *Sarsaparilla*, as *Sm. medica* (Vera Cruz), *S. Purhampuy* (Peru), *S. syphilitica* (Brazilian), *S. officinalis* (Jamaica), *S. glycyphylla* (Australia); *Smilax aspera* and *excelsa*, natives of S. Europe, have similar properties. *Smilax China* has a fleshy root, said to possess similar properties. *S. Pseudo-China* is largely used in domestic medicine in the United States. *Paris*, *Trillium*, and *Medeola* are more allied to the active Liliaceæ in their properties. *Paris quadrifolia*, a curious herb growing in groves in this country, is said to be a narcotic and poison; *Medeola virginica* is emetic and diuretic. The species of *Trillium* are violent emetics.

## ORDER CXLIII. LILIACEÆ. LILIES.

*Class.* Coronarieæ, *Endl.* *All.* Liliales, *Lindl.* *Coh.* Liliales, *Benth. et Hook.*

505. *Diagnosis.*—Herbs with parallel, sessile or sheathing leaves, regular perfect 6- (rarely 4-)androus flowers, with the petaloid 6-merous perianth free from the 2–3-celled ovary; anthers introrse, attached by a point; style single; albumen fleshy.

### *Character.*

*Perianth* free, of 6 pieces in 2 circles (fig. 432), distinct or united, mostly of similar colour, and regular.

*Stamens* 6, introrse, inserted on the segments of the perianth.

*Ovary* free, 3-celled, with numerous anatropous or amphitropous ovules on axile placentas; *styles* simple; *stigma* 3-lobed or undivided, sometimes sessile.

*Fruit* dry and capsular, loculicidally valvate, or succulent and indehiscent; *seeds* with the embryo mostly in the axis of fleshy albumen.

Fig. 432.

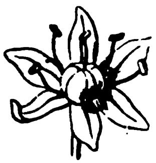


Fig. 432. Flower of *Scilla*.

Fig. 433.

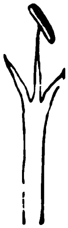


Fig. 433. Stamen of *Allium*.

Fig. 434.

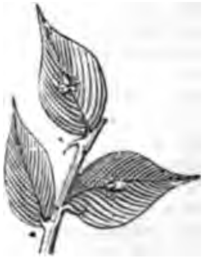


Fig. 434. Inflorescence of *Ruscus*.

ILLUSTRATIVE GENERA.

Tulipa, *Tournef.*
Fritillaria, *L.*
Lilium, *L.*
Funkia, *Spr.*
Agapanthus, *Hérit.*
Phormium, *Forst.*
Sanseviera, *Thunb.*
Aloe, *Tournef.*
Yucca, *L.*
Allium, *L.*
Scilla, *L.*
Muscari, *Tournef.*
Hyacinthus, *L.*
Asphodelus, *L.*
Asparagus, *L.*
Dracæna, *Vand.*
Convallaria, *Desf.*
Ruscus, *Tournef.*

**Affinities.**—Looking only at the more familiar forms of the Liliaceæ, the characters of the flowers are very definite, although the habit of the plants brought together in this Order varies extremely; but there exist certain genera of petaloid Monocotyledons, whose relations appear closest to Liliaceæ, which form links of chains leading off in very varied directions, through the Orders of this Subclass. *Tulipa* and the allied genera, with usually distinct lobes to the perianth and versatile anthers, are bulbous herbs: *Funkia, Hemerocallis,* and other genera have a more or less tubular perianth, and often tuberous roots instead of bulbs; *Aloe* has thick succulent leaves on a perennial stem; *Yucca* has a Palm-like stem and rigid leaves. *Scilla, Allium,* and their allies are bulbous herbs, differing chiefly from the group to which *Tulipa* belongs in the firmly fixed anthers, and a membranous spathe enclosing the inflorescence when young. *Anthericum* and others resemble the last, but have tuberous or fibrous roots; *Aphyllanthes* is a plant with the habit of Juncaceæ and the flower of Liliaceæ; *Xanthorrhœa,* a genus belonging to the same group, forms a woody trunk like *Yucca,* or a small Palm. *Asparagus* and its allies, including *Convallaria, Smilacina, Ruscus,* &c., together with the arborescent *Dracænæ* and *Cordylines,* are Liliaceæ with succulent fruits, and scarcely separable from Smilaceæ. *Conanthera* and its allies, with the general structure of Liliaceæ, have the perianth more or less adherent, thus approaching Amaryllidaceæ. *Wachendorfia, Lophiola,* and others have the free ovary of Liliaceæ, but triandrous flowers and the foliage of Hæmodoraceæ. *Aspidistra* bears some resemblance in its foliage to Zingiberaceæ, while the character of the flowers approaches that of the complete Araceæ. *Ophiopogon* and *Peliosanthes* are likewise doubtfully placed here; but their structure is not satisfactorily made out.

We see, therefore, that the Liliaceæ have widely spreading relations, although the typical forms are at once distinguishable. The superior ovary separates them from Amaryllidaceæ, and the introrse stamens and closely coherent carpels from the Melanthaceæ. Their very near connexion with Smilaceæ is noticed above; they have a more distant affinity to the Palms and to the Juncaceæ in the general structure of the flowers, differing from both in habit, fruits, and seeds. Gilliesiaceæ and Pontederaceæ are scarcely more than aberrant Liliaceæ with irregular flowers.

The structure of the arborescent stems of *Dracæna, Cordyline, Xanthorrhœa, Yucca,* &c. has attracted considerable attention, since, contrary to the usual habit of Monocotyledons, their trunks sometimes increase more or less in thickness with age. However, the central axis corresponds essentially to that of the Palms; only a peculiar rind or false bark exists, capable of increase by layers, somewhat in the same way as the liber of Dicotyledons.

**Distribution.**—A large Order, the members of which are very variously and widely distributed; the bulbous kinds common in temperate climates, the fibrous-rooted with them and in warmer localities: the succulent-leaved *Aloes* chiefly S.-African; the arborescent forms mostly subtropical.

**Qualities and Uses.**—Many of the Liliaceæ have active properties, and the juices, the fibres, or the fruits afford products of value in the arts. The juice of the succulent-leaved *Aloes* dries into a kind of resin, medicinal Aloes, one of the most valuable of purgatives; the species from which it is usually obtained are *Aloe spicata, vulgaris, socotrina,* &c. The bulb of *Urginea maritima* is the Medicinal Squill, valuable as an expectorant and diuretic, but emetic and purgative in large doses. *Pancratium* (often cultivated for its flowers) has similar properties. The leaves and roots of *Erythronium* (Dog's-tooth), of the Hyacinths (*Hyacinthus orientalis, lusitanicus, Scilla nutans*), and the genera *Muscari*, *Ornithogalum*, *Gagea*, all have emetic qualities; the tuberous fibrous roots of *Asparagus* and of the Lily of the Valley (*Convallaria majalis*) are said to be purgative; those of Solomon's Seal (*Convallaria Polygonatum*) are acrid. The bulbs of the Crown-imperial (*Fritillaria imperialis*) and other species, and of *Gloriosa superba*, are said to be very poisonous. The bulbs of the genus *Allium* have milder properties, and at the same time possess a pungent quality, on account of which they are extensively grown for food, the large and milder cultivated kinds being esculent vegetables; the smaller and more pungent are valued for imparting flavour. *Allium Cepa* is the Onion; *A. Porrum*, the Leek; *A. sativum*, Garlic; *A. Schœnoprasum*, the Chive; *A. ascalonicum*, the Shallot; *A. Scorodoprasum*, the Rocambole: "Spanish Onions," coming from Spain, Portugal, and Egypt, are mild varieties of the common Onion, the bulb growing to a larger size, and forming less of the pungent secretion. The bulbs of *Lilium pomponium* constitute an important article of food in Kamtschatka; the tubers of *Camassia esculenta* are eaten by the North-American Indians. The woody roots of *Dracæna terminalis* (*Cordyline Ti*) are eaten, roasted, by the Sandwich Islanders; sugar and fermented liquor are likewise prepared from its juice; its leaves furnish fodder for cattle, as do those of the Grass-tree (*Xanthorrhœa*) in Australia; the bases of the young leaves and the heart of the buds of the latter are sometimes used as esculent vegetables. The table Asparagus consists of the very young annual shoots (*turiones*) of *Asparagus officinalis*, rendered succulent by cultivation. Astringent resins are obtained from some kinds: *Dracæna Draco*, the Dragon-tree of Teneriffe, yields the true Dragon's Blood, formerly much used in medicine, but now seldom met with, the resin of *Pterocarpus* (Leguminosæ) being substituted. *Xanthorrhœa arborea* yields Botany-Bay Gum, which is yellow, pungent, and smells like Benzoin when burnt. *Phormium tenax* is the New-Zealand Flax plant; the fibre of the leaves is very tenacious, as is that of various species of *Sanseviera*, known as African Hemp and Bowstring Hemp in Africa and the East Indies. Active properties and uses are attributed to many other less-known species. A great number of Liliaceæ, hardy and tender, ornament our gardens and stoves, as will be recognized from the list given above. *Polianthes tuberosa* is the Tuberose, celebrated for its fragrance. The Butcher's Broom (*Ruscus aculeatus*) is remarkable for its foliaceous peduncles (fig. 434) and really almost leafless stems; and the fully developed flowering-stem of *Asparagus* has only needle-shaped branches simulating leaves.

## ORDER CXLIV. MELANTHACEÆ. THE COLCHICUM ORDER.

*Class.* Coronarieæ, *Endl.* *All.* Liliales, *Lindl.* *Coh.* Liliales, *Benth. et Hook.*

506. *Diagnosis.*—Herbs with bulbous, tuberous, or fibrous roots, regular 6-merous and 6-androus flowers, the 6-parted petaloid or green perianth free (or nearly so) from the 3-celled ovary; 3 more

or less distinct styles, and extrorse adnate anthers; capsule 3-valved, septicidal, or sometimes loculicidal; seeds with a membranous testa; the embryo minute, in fleshy or horny albumen.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Tofieldia, *Huds.* | Melanthium, *L.* | Bulbocodium, *L.* |
| Asagræa, *Lindl.* | Uvularia, *L.* | Colchicum, *Tournef.* |
| Veratrum, *Tournef.* | | |

**Affinities.**—This Order stands very near to Liliaceæ and to Juncaceæ: from both there is a general distinction in the extrorse anthers and the septicidally tripartible capsule; but neither of these characters is absolutely general. The position of the anthers must be examined in the bud, as they become disarranged by their weight and dehiscence in the open flower. *Uvularia* has a loculicidal capsule and united styles, and thus approaches Liliaceæ through *Erythronium*; while *Streptopus* and *Disporum* approach in character to Smilaceæ, having a baccate fruit, and the latter arrow-shaped anthers somewhat like *Paris*. *Colchicum* resembles in habit *Crocus* among the Iridaceæ, and *Sternbergia* among the Amaryllidaceæ. *Tofieldia* has introrse anthers, and approaches Juncaceæ both in this respect and its habit; but its pods are septicidal.

**Distribution.**—A considerable group, generally diffused; most abundant in Europe, N. America, and N. Asia.

**Qualities and Uses.**—More or less poisonous, with acrid, purgative, emetic, and sometimes narcotic action; several of the more active species yield valuable medicines. Of *Colchicum autumnale*, called Meadow Saffron or Autumn Crocus, both the corms and seeds are very active; *Veratrum album*, White Hellebore, *V. nigrum*, *V. Sabadilla*, *V. viride* (N. America), *Asagræa officinalis* (Sabadilla or Cevadilla of Mexico), all share the acrid narcotic qualities, poisonous or medicinal, according to the dose. Most of the other genera are suspicious or dangerous, except perhaps the *Uvulariæ* (N. America), which are said to be merely astringent.

## ORDER CXLV. JUNCACEÆ. RUSHES.

*Class.* Coronarieæ, *Endl.* *All.* Juncales, *Lindl.* *Coh.* Liliales, *Benth. et Hook.*

507. *Diagnosis.*—Grass-like or sedgy herbs, with fibrous roots, or a subterraneous rhizome, with jointed stems, often capitate inflorescence, and a regular persistent perianth of 6 similar scale-like pieces (fig. 422); stamens 6, or rarely 3, with introrse anthers; ovary 1–3-celled, producing a 3-valved, 3- or many-seeded, or sometimes a 1-celled and, by suppression, 1-seeded capsule; embryo minute, in fleshy or horny albumen.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Luzula, *DC.* | Juncus, *DC.* | Narthecium, *Mœhr.* |

**Affinities.**—With Juncaceæ are included by Lindley a number of genera which are regarded as doubtful, or established as separate Orders by some writers, such as *Astelieæ*, a group of woolly-leaved epiphytic plants of the southern hemisphere, and *Kingieæ*, plants with a stem like *Xanthorrhœa* and a 1-seeded fruit, and some others. The genus *Juncus* (Rush) relates the Order to Liliaceæ, from which the chief difference lies in the habit, the small embryo, and the glumoid character of the segments of both circles of the perianth; *Narthecium* connects them; from Xyridaceæ the latter character divides them. *Xerotes* approaches the Palms in the character of the flowers; and this is associated with *Kingia*, which has an arborescent habit. The scaly perianth connects them with Cyperaceæ, Restiaceæ standing between and differing from the Juncaceæ in trifling points which will be noted under that Order.

**Distribution.**—A considerable group, the members of which are natives chiefly of cold or temperate regions; some occur in tropical Australia.

**Qualities and Uses.**—Without important properties in most cases. The leaves of Rushes (species of *Juncus*) are largely used for making mats, chair-bottoms, &c.; and the parenchyma or "pith" of the cylindrical leaves and stems was much used until recently for making the wicks of rush-lights; this substance has a beautiful microscopic structure, being formed of regular stellate cells.

(XYRIDACEÆ are sedge-like herbs with equitant leaves sheathing the base of a naked scape, which is terminated by a head of perfect 3-androus flowers, with a glumaceous calyx, a regular corolla, and extrorse anthers; the 3-valved, mostly 1-celled capsule containing several or many orthotropous seeds, with a minute embryo at the apex of fleshy albumen. In habit these plants approach the Glumaceous Orders, as Cyperaceæ; but the flowers are petaloid as regards the inner circle of organs, or corolla, nearly approaching Commelynaceæ, from which they differ in having epipetalous extrorse stamens, in the scaly calyx, and general habit. They are natives of the tropics or adjoining regions. Various species of *Xyris* are used as remedies for cutaneous affections both in India and America.)

## ORDER CXLVI. COMMELYNACEÆ. SPIDER-WORTS.

*Class.* Enantioblastæ, *Endl.* *All.* Xyridales, *Lindl.* *Coh.* Commelynales, *Benth. et Hook.*

508. *Diagnosis.*—Herbs with fibrous, sometimes thickened roots, jointed and often branching leafy stems, and chiefly perfect and 6-androus, often irregular flowers, with the perianth free from the 2–3-celled ovary, and having a distinct green calyx and a coloured corolla, each of 3 parts, the calyx persistent; stamens 6, all fertile or some abortive, often very peculiar in form; capsule 2–3-celled; seeds few (2) in a cell, attached by a linear hilum; embryo pulley-shaped, remote from the hilum, in dense fleshy albumen.

ILLUSTRATIVE GENERA.

Commelyna, *Dill.* | Tradescantia, *L.*

**Affinities, &c.**—This Order, to which belongs the garden Spider-wort

(*Tradescantia virginica*), may be regarded as one of the groups intermediate between the Orders with 6-merous glumoid perianth, like the Juncaceæ, and the petaloid forms like Liliaceæ. The jointed solid stems of *Tradescantia* are interesting in regard to the comparative structure of Monocotyledonous stems; they emit roots freely from the nodes like Grasses. The hairs of the filaments of the stamens of *Tr. virginica* are classic objects to the botanist, from the discovery in them of the rotation of the cell-sap in non-aquatic plants. The rhizomes of *Commelyna cœlestis*, *tuberosa*, and others contain starch and mucilage, and are used as food in India. Some of the species are said to have medicinal properties. They are natives of India, Australia, Africa, and the West Indies—a few of North America. *Tradescantia virginica* is hardy in our gardens.

(Pontederaceæ are a small Order of aquatic herbs with perfect more or less irregular flowers in a spathe; the petaloid, 6-merous perianth free from the 3-celled ovary; the 3 or 6 mostly unequal or dissimilar stamens inserted in its throat. They are separated from Liliaceæ chiefly by the irregular flowers, the persistent perianth rolling inwards after flowering, and by the mealy albumen of their seeds. They are natives of America, North and South India, and Africa, and do not appear to have any important properties. Some of the *Pontederiæ* are usually grown in stoves where there is a tank, on account of their blue or yellow flowers.)

(Mayaceæ consist of four species of *Mayaca*, little Moss-like plants occurring in America, from Brazil to Virginia, separated from Commelynaceæ on account of their habit, 1-celled anthers, 1-celled ovary with parietal placentas, and the carpels opposite the inner lobes (petals) of the perianth; they have no useful properties.)

(Gilliesiaceæ are a small Order of plants of somewhat anomalous structure, related to Liliaceæ; they are bulbous herbs with spikes of flowers which have a double circle of petaloid envelopes, 6 or 8 subulate processes, then a cup-like or labelloid organ bearing 3 or 6 anthers on its inner surface, and a 3-celled ovary. Lindley regards the petaloid envelopes and subulate processes all as bracts, and the structure on which the anthers are borne as the perianth. Other authors are opposed to this view. *Gilliesia*, Lindl., and *Miersia*, Lindl., are both Chilian genera.)

(Philydraceæ are herbs with fibrous roots, ensiform leaves with equitant bases; flowers in a persistent spathaceous bract, without a calyx, but with a 2-petalous corolla; 3 coherent stamens, of which the 2 lateral are barren and petaloid, and the middle has a 2-celled anther, the whole adherent to the anterior lobe of the perianth; the ovary superior, 3-celled, with axile placentas; seeds numerous, with an embryo in the axis of fleshy albumen. This Order consists of two plants, *Philydrum lanuginosum* (Australia) and *Hetæria pygmæa* (China), exhibiting, with a superior ovary, appearances analogous to those in the epigynous group of Orchidaceæ and their allies. Lindley regards them as related to Commelynaceæ and Xyridaceæ; but they would appear to be rather a kind of perigynous Zingiberaceæ. They have no known uses.)

## ORDER CXLVII. ORCHIDACEÆ. ORCHIDS.

*Class.* Gynandræ, *Endl.* *All.* Orchidales, *Lindl.* *Coh.* Amomales, *Benth. et Hook.*

509. *Diagnosis.*—Herbs, distinguished by their irregular flowers, 6-merous perianth adherent to the ovary; stamen (1, or very rarely 2) gynandrous, pollen cohering in waxy or mealy masses; ovary inferior, placentas parietal.

### *Character.*

*Perianth* mostly petaloid, adherent, in two circles; the outer circle of three pieces (*sepals*), distinct or more or less coherent below, two lateral and one anterior (or posterior when the ovary is twisted); the inner circle of three pieces (*petals*), or rarely one, alternate with the sepals, two lateral, and one (the *labellum*) posterior (or, by the twisting of the ovary, anterior) (figs. 435 & 436), usually longer and larger than the others, variously formed, with or without appendages, sometimes divided into 3 regions by contractions, forming *hypochilium* (at the base), *mesochilium*, and *epichilium*; free, or more or less adherent to the *column*.

Fig. 435.

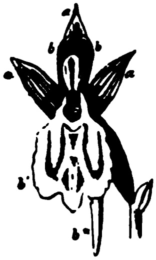


Fig. 436.

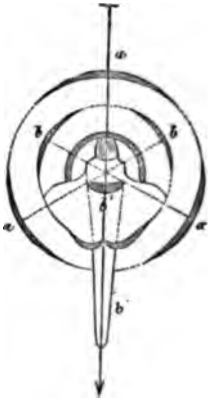


Fig. 437.

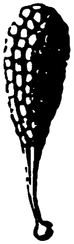


Fig. 435. Flower of *Orchis*, and
Fig. 436. Diagram of ditto: *a, a, a*, sepals; *b, b*, petals; *b'*, labellum; *b''*, spur.
Fig. 437. Clavate pollen-mass and caudicle of *Orchis*.

*Stamens* gynandrous, the filaments confluent with the style into a *column*, bearing mostly 1 perfect *anther* on the side turned away from the labellum, with 2 lateral processes (abortive anthers), or, rarely, 2 perfect lateral *anthers* with an abortive process next the odd sepal; the *pollen* pulverulent, or in grains, more or less coherent, or in definite waxy masses which are free or provided with a pedicel or *caudicle* (fig. 437), which adheres to a gland or glands at the apex or rostellum of the stigma.

*Ovary* inferior, 1-celled, with 3 double parietal placentas bearing numerous anatropous ovules; *style* 1, confluent with the filaments into the *column*, which is surmounted by a 3-merous, mucous, discoid *stigma* facing the labellum, its lobes alternating with the lines of placentation; the lateral lobes usually abortive, but sometimes forming divergent processes, the odd lobe more or less developed into a beak (*rostellum*) bearing 1 or 2 glands.

*Fruit* mostly a capsule bursting by 3 valves, bearing the placentas in the middle, separating from the midribs of the carpels, which remain as an open framework; rarely a fleshy indehiscent pod; *seeds* very numerous and extremely small, consisting of a cellular nucleus without distinct radicle or plumule, enclosed in a loose membranous or rarely crustaceous testa.

### ILLUSTRATIVE GENERA.

Malaxis, *Swz.*
Dendrobium, *Swz.*
Epidendrum, *L.*
Cattleya, *Lindl.*
Vanda, *R. Br.*
Phalænopsis, *Bl.*

Aërides, *Lour.*
Oncidium, *Swz.*
Odontoglossum, *H.B.K.*
Stanhopea, *Frost.*
Maxillaria, *Fl. Per.*
Catasetum, *Rich.*

Orchis, *L.*
Ophrys, *Swz.*
Vanilla, *Sw.*
Epipactis, *Haller.*
Cypripedium, *L.*

**Affinities.**—The comparative anatomy of this very extensive and curious Order forms one of the most interesting subjects in botanical Morphology. In the greater part of the genera the ideal Monocotyledonous type is departed from in several particulars, as:—in a more or less considerable irregularity of the perianth, especially in the condition of the *labellum*; in the circumstance that the filaments are confounded with the style into a central organ, prolonged from the inferior ovary, called the *column*, and that generally 2 out of (at least) 3 anthers are abortive, while the pollen is frequently less developed than usual, the process of subdivision into distinct cells or granules being arrested, so that it remains in compound masses of various degrees of magnitude and of more or less firm and even waxy consistence. In some cases, however, the perianth is almost regular, so as to resemble that of some of the genera of Iridaceæ; and in *Cypripedium* we find 2 anthers developed and only 1 abortive. Among the other remarkable peculiarities of the structure are processes of various kinds occurring upon the column and labellum, which there is reason to regard as indications of abortions of staminal organs. These have given rise to the opinion that the elements of 2 circles of stamens exist in this Order, of which 5 are usually suppressed, the perfect one belonging to an external circle of 3, while in *Cypripedium* the 2 which are developed are members of the inner circle of 3, one of which, with the entire outer circle, is abortive. This view is supported by numerous exceptional instances, in which some or all of the ordinarily suppressed stamens are present, and by the anatomical construction, which reveals the existence of as many bundles of vascular tissue in the column and ovary as there are stamens and carpels. The suppression of 2 out of 3 stamens connects this Order with Marantaceæ and Zingiberaceæ, where the same phenomenon exists in a different modification, as mentioned under those Orders; the Apostasiaceæ have 2 stamens only, with their filaments adhering to the lower part of the style. The ovary is apparently formed of 3 carpels, with the stigmas simple, since they alternate with the placentas: Lindley supposes the ovary to be formed of 6 carpels, 3 fertile and 3 barren; but this seems contrary to analogy and without sufficient independent support; in Apostasiaceæ, Marantaceæ, and Zingiberaceæ the ovary is 3-celled, or sometimes imperfectly so in the last, from the margins not meeting in the centre. The seeds, which are very minute, are of simple organization; the ovules, at the time of fertilization, consist solely of an embryo-sac with 2 integuments; and the ripe seed presents an embryo devoid of distinct organs (cotyledon and radicle), enclosed in a loose testa—in this respect exhibiting a relationship to Burmanniaceæ.

The labellum sometimes exhibits irritability, moving spontaneously or when touched (*Megaclinium*, *Bolbophyllum*, &c.): its forms are most varied and strange, often causing the entire flower to resemble an insect or some other living object. The rostellum and stalk of the pollen-masses are also endowed with contractile properties. In *Catasetum* these are so powerful as to cause the sudden forcible ejection of the pollen-masses from the anther-cells, when the rostellum or other sensitive organ is touched, as by the proboscis of an insect. Insects visiting orchid flowers, for the sake of the honey in the spur or nectary, come into contact with the rostellum, and thus liberate the pollen-masses. These latter adhere firmly to the insect's back by means of the gland at the end of the stalk, so that the pollen-mass is conveyed to another flower. It must, however, be remarked that if the pollen-mass retained the nearly vertical direction it had on its exit from the anther, it would, when introduced by the insect into another flower, strike against the anther, and not against the stigma. In order to place the pollen in such a position that it shall impinge on the stigma, the caudicle or stalk of the pollen-mass contracts so as to give the pollen-mass the requisite horizontal direction. This movement can readily be seen by thrusting the point of a pencil into a flower against the rostellum, when the pollen-masses will adhere to the pencil, and may be withdrawn from the anther-case, and, if watched, will be seen to bend downwards, in the manner just described, immediately after their removal from the anther. These movements will be again alluded to in the physiological portion of this work.

Two extremely distinct forms of the perianth sometimes present themselves on the same flower-spike, so that the same species has received two specific titles, and even three distinct generic names:—*e. g.*, *Monachanthus*, *Myanthus*, and *Catasetum*, now all included in the last named genus, and *Cycnoches ventricosum* and *Egertonianum*, now known to be forms of one and the same species. This was considered a most anomalous circumstance till it was shown by Darwin that the different forms represented different sexes, the male flowers being different from the female. The Orchidaceæ are terrestrial in temperate climates, forming subterraneous tubers (§ 49) or tuberously enlarged fibrous roots, from which the flowering-stem shoots up afresh every season. In warm and moist climates they are very frequently epiphytic, hanging on the branches of trees, or even attaching themselves to rocks and other foreign objects. These kinds generally form some kind of stem-tuber, either from the lower internodes of the axis which has just flowered, or of a new axis, sometimes from the whole of the internodes of a long jointed leafy axis, &c. The roots which hang down from them are soft and delicate at the apex; and the epithelial cells exhibit spiral-fibrous thickening of a peculiar kind.

**Distribution.**—Orchids are very numerous, and occur in almost all parts of the globe, except the very coldest, or in very dry regions. In temperate climates they occur chiefly in shady woods, damp pastures, or open calcareous downs; but they are most abundant in damp situations in the tropics.

**Qualities and Uses.**—The properties of these plants are generally unimportant. The subterranean tubers of some form nutritious food, from the presence of a gummy substance: that of a native species, *Orchis mascula*, was formerly collected and sold for the preparation of Salep; and other kinds are eaten in India. Some of the South-American yield a kind of vegetable glue; *Aplectrum hyemale*, the North-American Putty-root, is used for making a cement for china. The most important plants, perhaps, are *Vanilla planifolia* and other species, and a species of *Sobralia*, the dried pulpy pods of which furnish the Vanilla used for flavouring chocolate and confectionary. A few others are described as having medicinal properties of various kinds.

(APOSTASIACEÆ is a small Order of perennial herbs nearly related to Orchidaceæ, bearing a regular perianth and 2 or 3 stamens which are confluent by their filaments with the lower part of the style (the anthers free), forming a kind of column, prolonged above into a filiform process with a 3-lobed stigma; ovary 3-celled, with axile many-seeded placentas; seeds apparently as in Orchidaceæ. These plants differ from Orchids chiefly in the free condition of the upper part of the style, and the 3-celled ovary; but as the latter character is inconstant in some Monocotyledonous Orders, probably this Order should be united with Orchidaceæ: they are near to Burmanniaceæ also; but that Order has free stamens. Lindley regards this Order as connecting Orchidaceæ with Amaryllidaceæ through Hypoxidaceæ. They are natives of damp woods in tropical India, and are without known properties. Genera: *Apostasia*, Bl., &c.).

(BURMANNIACEÆ are small annual herbs, often with minute and scale-like leaves, or those near the root grass-like; the flowers perfect, with a 6-cleft petaloid perianth, the tube of which adheres to the 1-celled or 3-celled ovary; stamens 3, distinct, introrse, and opposite the inner segments of the perianth, or 6 and extrorse; stigmas 3; capsule many-seeded; the seeds very minute, with a homogeneous nucleus in a loose membranous testa. Natives of the tropics of America, Africa, and Asia. Some are probably parasitical. The affinities of these plants are rather obscure; they apparently agree with Iridaceæ in the character of the flowers, but differ in the position and number of the stamens; while, by the seeds resembling those of Orchidaceæ, they form a connecting link between these two Orders. They are said to be bitter and astringent, but are unimportant in these respects. Genera: *Burmannia*, L.; *Thismia*, Griff., &c.)

## ORDER CXLVIII. ZINGIBERACEÆ. THE GINGER ORDER.

*Class.* Scitamineæ, *Endl.* *All.* Amomales, *Lindl.* *Coh.* Amomales, *Benth. et Hook.*

**510. *Diagnosis.***—Herbaceous plants with a creeping rhizome; leaves broad, with a sheathing petiole, and numerous parallel veins diverging from a midrib; flowers spiked or racemose, with spathaceous membranous bracts; perianth adherent, irregular, in three circles of three parts, one petal being larger in each of the two inner circles; stamens 3, distinct, 2 abortive, and the fertile one posterior, opposite the labellum or large segment of the innermost perianthial whorl; anther 2-celled; ovary 3-celled, or with the dissepiments imperfect; seeds numerous, with the embryo in a sac (*vitellus*) within the albumen.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Zingiber, *Gærtn.* | Hedychium, *Kœnig.* | Costus, *L.* |
| Amomum, *L.* | Alpinia, *L.* | |

**Affinities.**—This Order is nearly related to Marantaceæ, Orchidaceæ, and the allied Orders, but may always be distinguished by the only fertile stamen being situated next the axis (posterior), not next the bract (anterior) as it is in Orchidaceæ (before the ovary becomes twisted), or lateral as it is in Marantaceæ; the ovary is usually 3-celled, like that of Marantaceæ, but the embryo is contained in a special sac or vitellus, which is not present in the seeds of either Marants or Orchids.

**Distribution.**—A large Order, consisting mostly of tropical plants; the greater part East-Indian, but a few occurring in America, in Africa, and in Japan.

**Qualities and Uses.**—Remarkable for the pleasant aromatic and stimulant qualities of the rhizomes and the seeds of many kinds; some are astringent, many yield starch, and some colouring-matters.

Ginger is the rhizome of *Zingiber officinale*: preserved ginger is made from the younger parts of the rhizomes. Cardamom seeds are obtained from *Amomum Cardamomum* (Round Cardamoms), *A. angustifolium* (Madagascar Cardamoms), *A. maximum*, *A. aromaticum*, *Elettaria major* (Ceylon), and *E. Cardamomum* (Malabar). Turmeric consists of the yellow-coloured rhizomes of *Curcuma longa*; the starchy rhizomes of some East-Indian species of *Curcuma* furnish Arrow-root. Galangale-root, which has properties resembling those of Ginger, consists of the rhizomes of *Alpinia Galanga* and *racemosa*; Zedoary, of those of *Curcuma Zedoaria* and *Zerumbet*. *Amomum Grana Paradisi* yields the Grains of Paradise, used as stimulants, and also for giving pungency to spirits and beer. Many of the species have very beautiful blossoms, and are cultivated in stoves on that account. The bright colouring is found sometimes in the bracts, sometimes in the perianth, as in *Hedychium coronarium*.

## ORDER CXLIX. MARANTACEÆ. THE ARROW-ROOT ORDER.

*Class.* Scitamineæ, *Endl.* *All.* Amomales, *Lindl.* *Coh.* Amomales, *Benth. et Hook.*

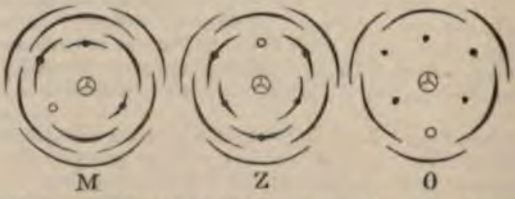
511. *Diagnosis.*—Herbaceous plants with creeping rhizomes, resembling Zingiberaceæ in habit, but with the perianth more irregular, and the inner segments often abortive; the 3 stamens petaloid, 2 barren, and 1 lateral fertile 2-lobed, with a 1- (2?)-celled anther on one of its lobes; ovary inferior, 1–3-celled, with numerous albuminous seeds; embryo not enclosed in any special sac.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Maranta, *Plum.* | Canna, *L.* |

**Affinities.**—The affinities are those of Zingiberaceæ, from which this Order is separated by the place of its fertile stamen (lateral) and by the absence of a vitellus or special sac round the embryo. If we assume the Orchidaceæ, as mentioned under that Order, to have the rudiments of a double series of stamens, the relations of Orchidaceæ, Zingiberaceæ, and Marantaceæ are very close, and yet their distinctions very clear (fig. 438).

Fig. 438.



Diagrams of the flowers of Marantaceæ (M), Zingiberaceæ (Z), and Orchidaceæ (O). The small open circles are fertile stamens; the black dots abortive stamens; the black dots with the broad line scored through are petaloid stamens.

*Orchidaceæ*, with a double perianth, and two circles of stamens, have the anterior stamen (belonging to the outer circle) developed, the rest abortive, or present in the form of horns, ridges, &c. (O); or, in *Cypripedium*, they have the 2 lateral stamens of the inner circle developed, the anterior and all those of the outer circle abortive.

*Zingiberaceæ*, with a double perianth, have the outer circle of stamens petaloid forming a third perianthial circle, the odd (posterior) stamen of the inner circle developed, the 2 lateral abortive (Z).

*Marantaceæ*, with a double perianth, have the outer circle of stamens more or less developed in a petaloid form, as a third perianthial circle, and one lateral stamen of the inner circle fertile—the other lateral stamen, with the posterior one, being abortive (M). Dr. Dickie has lately shown that the anther of *Canna* is in reality 2-celled.

**Distribution.**—The species are numerous, and natives chiefly of tropical America, Africa, and India.

**Qualities and Uses.**—The abundance of pure starch furnished by the rhizomes of many species constitutes the principal feature of the Marantaceæ considered from an economical point of view. True Arrow-root is obtained from *Maranta arundinacea*, *Allouyia*, and *nobilis* (West Indies), and *M. ramosissima* (East Indies). Tous-les-Mois is derived from species of *Canna*, probably *C. coccinea*, *Achiras*, *edulis*, &c. *Canna indica* is called "Indian shot" from its beautifully spherical seeds. Some of the species are cultivated in our stoves. Many of the species of *Calathea* and *Maranta* have beautifully coloured foliage.

## ORDER CL. MUSACEÆ. BANANAS.

*Class.* Scitamineæ, *Endl.* *All.* Amomales, *Lindl.* *Coh.* Amomales, *Benth. et Hook.*

512. *Diagnosis.*—Large herbaceous plants with long sheathing petioles forming a spurious stem; leaves large, with a strong midrib and parallel lateral veins; flowers enclosed in a spathe, hermaphrodite; perianth more or less irregular, adherent, petaloid, in two 3-merous rows; stamens 6, on the segments of the perianth, some always abortive; anthers 2-celled; ovary 3-celled, many-seeded, or rarely 3-seeded; fruit a capsule or succulent and indehiscent; embryo at the end of albumen.

### ILLUSTRATIVE GENERA.

Heliconia, *L.* | Musa, *Tournef.* | Strelitzia, *Banks.* | Ravenala, *Adans.*

**Affinities.**—With certain well-marked differences, these plants approach in some degree to the Marantaceæ and Zingiberaceæ in habit, especially in the character of the foliage, but the Musaceæ have 5 or 6 more or less perfect stamens and no staminodes; from the Amaryllidaceæ, which they resemble in the epigynous hexandrous structure, they differ in the irregular flowers, the general habit, and the character of the bracts or spathes.

**Distribution.**—A small Order, the species of which are generally diffused, wild or in culture, in the plains of the tropics, Cape of Good Hope, &c.

**Qualities and Uses.**—These plants are most valuable as sources of food and fibrous materials. *Musa paradisiaca*, the Plantain, and *Musa sapientum*, the Banana, are plants bearing gigantic leaves on long petioles, the imbricated sheaths of which form a pseudo-stem many feet high. They produce large clusters of pulpy fruit containing much sugar and starch, which form a very important article of food in the tropics. Several other species of *Musa* yield similar fruits. The leaves are used for thatching huts, or split up for plaited work of all kinds. The fibre of the petioles is a valuable material, especially that of *Musa textilis*, which is known as

Manilla Hemp. The young shoots are also eaten boiled. *Ravenala speciosa* has an edible seed; a quantity of watery juice exudes from its petioles when cut, whence it has been called *Arbre du voyageur*. *Strelitzia* is a genus with very handsome flowers, several species of which, as also of *Musa*, are often cultivated in stoves.

## ORDER CLI. AMARYLLIDACEÆ. AMARYLLIDS.

*Class.* Ensatæ, *Endl.* *All.* Narcissales, *Lindl.* *Coh.* Iridales, *Benth. et Hook.*

513. *Diagnosis.*—Chiefly bulbous and scape-bearing herbs, not scurfy or woolly, with linear flat root-leaves, and perfect, regular (or nearly so), 6-androus flowers; perianth petaloid, 6-parted, its tube adherent to the 3-celled ovary; the segments of the limb imbricated in æstivation; anthers introrse; fruit a 3-valved, loculicidal capsule or a 1–3-seeded berry; seeds with fleshy or horny albumen; radicle turned to the hilum.

### ILLUSTRATIVE GENERA.

Tribe 1. AMARYLLEÆ. *Bulbous plants, without a coronet.*
- Galanthus, *L.*
- Amaryllis, *L.*

Tribe 2. NARCISSEÆ. *Bulbous plants, with a coronet in the perianth.*
- Pancratium, *L.*
- Narcissus, *L.*

Tribe 3. ALSTRŒMERIEÆ. *Fibrous-rooted; sepals unlike the petals; no coronet.*
- Alstrœmeria, *L.*

Tribe 4. AGAVEÆ. *Fibrous-rooted; sepals and petals alike, valvate in æstivation; no coronet.*
- Agave, *L.*
- Fourcroya, *Vent.*

**Affinities.**—This epigynous Order contrasts with the hypogynous Liliaceæ; among its epigynous allies, Iridaceæ are distinguished by their 3 stamens and extrorse anthers: its nearest allies are Hæmodoraceæ and and Hypoxidaceæ, the characters of which are given below. The coronet of the *Narcisseæ* is sometimes regarded as a circle of abortive stamens, but is more probably an outgrowth from the tube of the perianth.

**Distribution.**—A large Order, the species of which are generally diffused, but, like Iridaceæ, have their maximum at the Cape of Good Hope. The *Narcisseæ* are common in Europe, while the genera unprovided with a coronet are very rare in Europe and North America, but abound in South Africa.

**Qualities and Uses.**—The Amaryllidaceæ are commonly characterized by active properties, the *Amarylleæ* and the *Narcisseæ* especially being emetic and purgative, and even poisonous; the juice of the bulb of *Hæmanthus toxicarius* is used by the Hottentots to poison arrows. The Snow-drop (*Galanthus nivalis*), Snow-flake (*Leucojum vernum*), the Daffodil (*Narcissus Pseudo-Narcissus*), with the other cultivated *Narcissi*, *Pancratium maritimum*, &c. act as emetics. Others are astringent; but starch is washed from the roots of some species of *Alstrœmeria*. The

*Agaves* are exceedingly valuable plants, having abundant innocuous saccharine sap, and large leaves containing excellent fibre. *Agave americana*, called by mistake the American Aloe, is the Hundred-years plant; but the statement that it lives 100 years before flowering is fabulous: it is a native of America, but is naturalized in some parts of S. Europe, and is planted, on account of its large spiny leaves, to form fences. From this and other species is obtained Pita thread, a valuable fibre; Pulque (a fermented liquor) and a brandy distilled from this are made by cutting the buds out of *Agave*-plants and collecting the sap, which exudes in great abundance when this operation is performed just before the flowering stem is pushed out; these plants are also called Maguey-plants. This Order affords a number of beautiful flowers, more permanent than Iridaceæ, and often attaining a very large size. Most of them are annual flowerers; but the *Agaveæ*, having remarkable foliage, like that of the *Aloes* in Liliaceæ, produce flowering stems (sometimes many feet in height) after vegetating for a number of years, whence the story of the Hundred-years Aloe. *Sternbergia lutea* is supposed to be the Lily of the fields referred to by Christ.

(HYPOXIDACEÆ are a small Order of epigynous Monocotyledons, nearly related to Amaryllidaceæ, but differing in their habit, having hairy foliage and no bulbs, and in their usually strophiolate seeds having the radicle next the hilum. The 6 stamens, the imbricated, distinctly petaloid perianth, and the habit of the foliage separate them from Iridaceæ. They occur scattered in the warmer parts of the globe, and are apparently more or less bitter and aromatic. The tubers of some are eaten. Genera: *Curculigo*, Gærtn.; *Forbesia*, Eckl.; *Hypoxis*, L.; *Sauridia*, Harv.)

(HÆMODORACEÆ are herbs with fibrous roots, usually equitant leaves, and perfect 3–6-androus regular flowers, which are woolly or scurfy outside; the tube of the 6-parted perianth adherent to the whole surface, or merely to the lower part of the 3-celled ovary; anthers introrse; stamens opposite the petals when 3; seeds with cartilaginous albumen; radicle remote from the hilum. The structure of the genera included in this Order is rather irregular: from Amaryllidaceæ they are usually distinguished by the woolly tubular perianth, the equitant leaves, and, in some cases, by the 3 stamens; but none of these characters are without exception: from Iridaceæ the triandrous genera differ in the stamens being introrse and opposite the petals, which last character also separates them from Hypoxidaceæ. The radicle is said to be remote from the hilum, as in Hypoxids; while it is next it in Amaryllids and Irids. The *Vellozieæ* and *Barbaceniæ* are more or less arborescent, and in some degree branched, especially the former, which have a very remarkable aspect; in many respects they approach Bromeliads. The plants are natives of America, the Cape, and Australia, and have sometimes bitter and astringent properties, as *Aletris farinosa*. The roots often contain a red matter available as a dye, whence the name of Blood-roots; *Lachnanthes tinctoria* is used in America. The roots of several species of *Hæmodorum* are eaten, roasted, by the natives of Australia. Genera: *Hæmodorum*, Sm.; *Aletris*, L.; *Vellozia*, Mart.; *Barbacenia*, Vandelli.)

## ORDER CLII. IRIDACEÆ. THE FLAG ORDER.

*Class.* Ensatæ, *Endl.* *All.* Narcissales, *Lindl.* *Coh.* Iridales, *Benth. et Hook.*

514. *Diagnosis.*—Herbs with bulbs, corms, or rhizomes, equitant 2-ranked leaves, and perfect, regular or irregular flowers; the segments of the 6-parted petaloid perianth (fig. 439) convolute in the bud in 2 circles; the tube adherent to the 3-celled ovary; stamens 3, distinct or monadelphous; anthers extrorse; style 1; stigmas 3 (fig. 440), often petaloid (*Iris*); capsule 3-valved, loculicidal (figs. 441 & 442); seeds with horny or hard fleshy albumen (fig. 443).

Fig. 439.

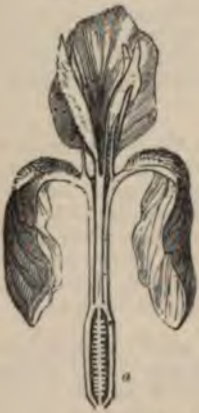


Fig. 440.

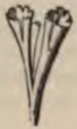


Fig. 442.

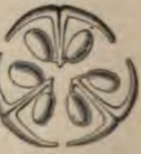


Fig. 441.

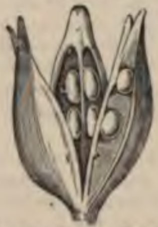


Fig. 443.

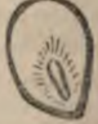


Fig. 439. Vertical section of the flower of *Iris*: *a*, inferior ovary.
Fig. 440. Stigmas of *Crocus*.
Fig. 441. Fruit of *Iris* burst.
Fig. 442. Plan of ditto.
Fig. 443. Section of seed of *Iris*.

ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Iris, *L.* | Gladiolus, *Tournef.* | Crocus, *Tournef.* |
| Tigridia, *Juss.* | Ixia, *L.* | |

**Affinities.**—Among the epigynous petaloid Monocotyledons, the Iridaceæ approach, by genera like *Crocus*, the Amaryllidaceæ, which, however, have 6 introrse stamens. The same character separates the epigynous Bromeliaceæ, which have some affinity with this family; Orchidaceæ differ in the gynandrous structure; Marantaceæ and Zingiberaceæ in their monandrous state, as also in the character of their foliage. The little *Order* Burmanniaceæ resembles Iridaceæ in many particulars, but differs in some essential points mentioned under that Order; and this is the case also with Xyridaceæ.

**Distribution.**—A large Order, diffused throughout temperate and warm climates, but especially abundant at the Cape of Good Hope.

**Qualities and Uses.**—The sap of many of these plants is more or less acrid, purgative, or emetic, as that of the Flags (*Iris*) generally, *Ferraria*, *Sisyrinchium*, &c. Saffron consists of the stigmas of the Saffron Crocus (*C. sativus*) and of *C. odorus* (Sicily). Orris-root, used in perfumery, is the rhizome of *Iris florentina*. The genera of this Order contribute a large share to our collections of garden-bulbs, as will be recognized from the plants already named; they are more remarkable for their beautiful but transient flowers than for any useful quality; the corms and rhizomes of some are said to be eaten, on account of the starch they contain, by the Hottentots and other races.

## ORDER CLIII. BROMELIACEÆ. THE PINE-APPLE ORDER.

*Class.* Ensatæ, *Endl.* *All.* Narcissales, *Lindl.* *Coh.* Iridales?, *Benth. et Hook.*

515. *Diagnosis.*—Herbs (or scarcely woody plants), nearly all tropical, the greater part epiphytes, with persistent dry or fleshy and channelled crowded leaves, sheathing at the bases, usually covered or banded with scurfy scales; perianth free or adherent, in two circles, the outer (sepals) often coherent, and differently coloured from the inner (petals), which are distinct and imbricated: stamens 6; ovary 3-celled, with numerous ovules on axile placentas; style single; stigma 3-lobed or entire, often twisted; seeds numerous, with a minute embryo in the base of mealy albumen; the radicle next the hilum.

ILLUSTRATIVE GENERA.

Ananassa, *Lindl.*
Bromelia, *L.*
Æchmea, *R. & P.*
Billbergia, *Thunb.*
Pitcairnia, *Hérit.*
Tillandsia, *L.*

**Affinities.**—Among the Bromeliaceæ are found both epigynous and hypogynous genera, as well as forms with a partially adherent perianth; on the whole, the tendency is to the former condition, whence the Order must be regarded as an ally of Amaryllidaceæ, from which it differs in habit and in the mealy albumen; from Iridaceæ it differs in these particulars and in the 6-androus stamens, while the style and stigma are somewhat similar. The character of the habit, and the often distinctly characterized calyx and corolla, offer a resemblance to Hydrocharidaceæ, which, however, have exalbuminous seeds. The fruit varies much in this Order, being commonly capsular; but in *Ananassa* the entire spike of inflorescence, together with the stem, becomes blended into a succulent sorosis (§ 290), the well-known Pine-apple. The scurfy epidermis of the leaves displays a very interesting microscopic structure.

**Distribution.**—A considerable group, the members of which are, for the most part, natives of tropical America; but some are now naturalized in West Africa and the East Indies.

**Qualities and Uses.**—Chiefly important for the fruit of *Ananassa*, fibres, colouring-matters, and other economic products. *Bromelia Pinguin* is used as a vermifuge in the West Indies. Many of these plants grow upon the branches of trees (epiphytic), and they appear to be capable of obtaining the greater part of their nourishment from the atmosphere their rigid, tough epidermis enables their succulent leaves to withstand the influence of a hot and dry atmosphere. *Tillandsia usneoides*, called Old-Man's Beard, is a common plant, forming a dense mass of dark-coloured fibres, which hang down from the boughs of the trees of the forests of tropical America, as Lichens do in colder climates. Most of the genera have brilliantly coloured flowers, sometimes in tall racemes and panicles, whence they are much esteemed as ornamental stove-plants.

## ORDER CLIV. HYDROCHARIDACEÆ.

*Class.* Ensatæ, *Endl.* *All.* Hydrales, *Lindl.* *Coh.* Hydrales, *Benth. et Hook.*

516. *Diagnosis.*—Aquatic herbs, with diœcious or polygamous regular flowers issuing from a spathe on the end of scape-like peduncles; floral envelopes in a single or double circle, in the fertile flowers united into a tube and adherent to the 1-9-celled ovary; placenta parietal; seeds without albumen.

### ILLUSTRATIVE GENERA.

| | |
|---|---|
| Udora, *Nutt.* | Stratiotes, *L.* |
| Vallisneria, *Mich.* | Hydrocharis, *L.* |

**Affinities.**—The sum or combination of the characters of this interesting Order keeps it apart from all other Monocotyledons, while the characters taken separately connect it with many. The inferior ovary and, in the case of *Stratiotes*, the habit connect them with Bromeliaceæ; the 3-merous petaloid flower and exalbuminous seeds with Alismaceæ; the 3-merous petaloid flower and 3-carpellary ovary with the Commelynaceæ, which, however, with a superior ovary, like the Alismaceæ, have albuminous seeds. The inferior ovary, numerous seeds, and general characters remove them from Naiadaceæ, with which they are often associated by habit, and the Araceæ, with which some would connect them; their spathe is scarcely more Araceous than that of Amaryllidaceæ. *Vallisneria* and *Elodea* (*Anacharis*) are plants well known to microscopists for the favourable opportunities they offer of examining the rotation of the protoplasm of the cells. *Hydrocharis*, a plant somewhat like a miniature Water-lily, is common in fresh-water ditches; and its sepals and rootlets are equally adapted for the microscopic investigation of living tissues. *Elodea canadensis* is the American Water-weed, which has increased so rapidly in our canals and ditches since its introduction from America some years since.

**Distribution.**—The species are not numerous; they are found in fresh water in Europe, N. America, E. Indies, and New Holland.

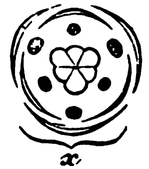
**Qualities and Uses.**—They appear to have no very active properties. *Hydrocharis* is said to be astringent.

## ORDER CLV. ALISMACEÆ.

*Class.* Helobiæ, *Endl.* *All.* Alismales, *Lindl.* *Coh.* Alismales, *Benth. et Hook.*

**517. *Diagnosis.*—Marsh-herbs, mostly with broad petiolate leaves and scape-like flowering stems; flowers perfect or monœcious, with a double perianth, consisting either of a green calyx and a coloured deciduous corolla, or of 2 circles of green scales, each of 3 pieces (fig. 444); ovaries 3, 6, or numerous, more or less distinct, and separating into as many nuts; seeds campylotropous or anatropous; embryo doubled, hook-shaped, or straight, without albumen.**

Fig. 444.



**Plan of flower of *Triglochin*: *x*, bract.**

ILLUSTRATIVE GENERA.

Subord. 1. JUNCAGINEÆ. *Perianth scaly; anthers always extrorse; ovule inverted; embryo straight.*

Triglochin, *L.*
Scheuchzeria, *L.*

Subord. 2. ALISMEÆ. *Internal circle of the perianth coloured; ovules solitary or twin; ovule and embryo curved.*

Alisma, *Juss.*
Actinocarpus, *R. Br.*
Sagittaria, *L.*

Subord. 3. BUTOMEÆ. *Internal circle of perianth coloured; ovules numerous all over the inner surface of the carpels; embryo curved.*

Butomus, *Tournef.*
Limnocharis, *H. & B.*

**Affinities.**—The *Alismeæ* bear considerable resemblance to the Dicotyledonous Order Ranunculaceæ, while *Butomeæ* have been compared with the Nymphæaceæ on account of the curious placentation; but there is hardly any real relationship in this latter case. On the other hand, the *Alismeæ* have some similarity to the Commelynaceæ, from which they are separated by the exalbuminous seed. This structure of the seed agrees with that of Naiadaceæ, with which this Order is connected by the *Juncagineæ*. *Scheuchzeria* in this last division approaches Juncaceæ.

**Distribution.**—A small group, the members of which inhabit marshy localities in all parts of the world; most abundant, perhaps, in temperate climates.

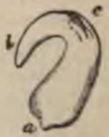
**Qualities and Uses.**—An acrid property is common in the foliage and in the rhizomes, but the latter are sometimes fleshy and farinaceous, and then may be eaten after the acridity is removed by cooking. *Sagittaria sinensis* is cultivated for food in China. Many are very handsome aquatic plants and are cultivated for the sake of their flowers.

## ORDER CLVI. NAIADACEÆ. THE POND-WEED ORDER.

*Class.* Fluviales, *Endl.* *All.* Hydrales, *Lindl.* *Coh.* Alismales, *Benth. et Hook.*

518. *Diagnosis.*—Immersed aquatic plants, with jointed stems and sheathing stipules within the petioles, or with sheathing bases to the leaves; inconspicuous, monœcious, diœcious, or perfect flowers, which are naked or have a free, scale-like perianth; the ovaries solitary or 2–4 and distinct, 1-celled, 1-ovuled; seed exalbuminous; embryo straight or curved (fig. 445), with a thin membranous testa.

Fig. 445.



Embryo of *Potamogeton*, with the testa removed: *a*, radicle; *b*, cotyledon; *c*, plumule.

ILLUSTRATIVE GENERA.

Caulinia, *Willd.*
Naias, *Willd.*
Zostera, *L.*
Ruppia, *L.*
Zannichellia, *Michel.*
Potamogeton, *L.*
Ouvirandra, *Thouars.*
Aponogeton, *Thunb.*

**Affinities.**—This Order agrees with Hydrocharidaceæ and Alismaceæ in the structure of its seeds, but differs in the simpler organization of the inflorescence, which, however, is connected with that of Alismaceæ in *Scheuchzeria*. Decaisne and Maout, following A. de Jussieu, keep distinct the Juncagineæ, Aponogeteæ, Potameæ, and Naiadeæ, all of which, with the exception of the first, are here included under Naiadaceæ. The groups established or maintained by the authors just cited are collectively characterized by the absence of a perianth or at least of a petaloid perianth, while they are separated one from the other by the form and direction of the embryo, which is straight and slender and with the radicle next the hilum in Juncagineæ, swollen and with the radicle away from the hilum in *Zostera*, swollen and with the embryo so curved that both its extremities are near the hilum in Potameæ, swollen and with the radicle directed to the hilum in Naiadeæ. The form of the stigmas, whether entire and truncate or linear and divided, is also relied on to distinguish the several groups. Some authors consider the inflorescence really spadiciflorous, and regard the scaly perianth, when present, as consisting of bracts surrounding imperfect unisexual flowers; and this idea is supported by the spathe-like bract which occurs in some genera (*Zostera* &c.). From this point of view they are related to Lemnaceæ; but the character of the seeds is diverse. The structure of these plants is generally very simple, consisting chiefly of cellular tissue of very delicate organization; in *Ouvirandra* the lamina of the full-grown leaf becomes a delicate lattice-like plate, the interspaces between the ribs being destroyed during expansion. *Zostera* is remarkable for its pollen-grains being tubular and destitute of an external coat.

**Distribution.**—The species are numerous, and are met with in still, fresh and brackish water, and in the sea (*Zostera*), in all parts of the world.

**Qualities and Uses.**—Apparently destitute of active properties. The leaves of *Zostera marina* are collected and dried on the sea-coast as a material for packing &c. in place of hay.

## Subclass 3. GLUMIFLORÆ.

519. **Monocotyledons, with the flowers collected into close spikelets, spikes, or heads, and the floral envelopes in the form of membranous scales; the leaves mostly linear, with long sheaths, tubular or slit; the seed albuminous.**

The plants of this Subclass are generally easily recognizable by the characters above given; but there is a superficial resemblance to them in the case of the inflorescence of the Juncaceæ, which stand more naturally among the Petaloid Monocotyledons, in spite of their scaly perianth; they are, moreover, easily distinguished from the true Glumaceæ by their distinctly regular 3-nary structure. The ordinary character of Monocotyledonous flowers is greatly disguised in this Subclass; but an explanation of the conditions in the apparently anomalous Grasses is given under that Order: in Cyperaceæ the floral envelopes are generally more or less completely suppressed; the female flower of *Carex* has a perianth composed of a tubular envelope; and something analogous to this occurs in Eriocaulaceæ, as the representative of a corolla, within the calycine scales.

## Order CLVII. GRAMINACEÆ. Grasses.

*Class.* Glumaceæ, *Endl.* *All.* Glumales, *Lindl.* *Coh.* Glumales, *Benth. et Hook.*

520. *Diagnosis.*—**Grasses (mostly herbaceous, rarely woody and arborescent), usually with hollow stems, with solid joints at the nodes; leaves alternate, distichous, with tubular sheaths slit down on the side opposite the blade, and a ligule (§ 79) at the base of the blade; the hypogynous flowers imbricated with 2-ranked glumes.**

### *Character.*

*Inflorescence* glumaceous, the flowers arranged in spikelets or *locustæ*, which are aggregated in spikes, racemes, or panicles; perfect, or sometimes monœcious or polygamous.

*Spikelets* mostly with two alternate and unequal bracts, called *glumes*, at the base (fig. 446), or enclosing the florets; the outer glume sometimes absent.

*Flowers* 2 or many, or rarely solitary with abortive rudiments of others, alternate on the rachis within the glumes, more or less overlapping from below.

*Perianth*: the outer circle or *calyx* represented by two scales (*paleæ* or *glumellæ*) (figs. 446–448, *b*, *b'*), one inserted a little above the other (alternate), the outer and lower simple, the inner or upper (sometimes called the flowering glume) with 2 primary ribs, and sometimes notched at the summit, the internal palea sometimes wanting; the inner circle (*corolla*) of 2 or 3 hypogynous scales (*lodiculæ* (fig. 448, $x$, $x$)), sometimes wanting; if 2 in number, collateral, alternate with the paleæ and next the outer, distinct or united.

Fig. 446.

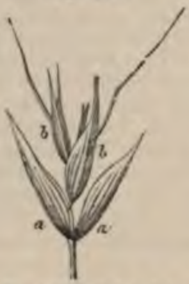


Fig. 447.

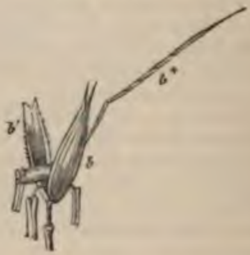


Fig. 446. Spikelet of *Avena*: $a$, $a$, glumes; $b$, $b$, outer paleæ of florets.
Fig. 447. Floret of *Avena*: $b$, outer palea; $b^*$, awn; $b'$, inner palea.

Fig. 448.

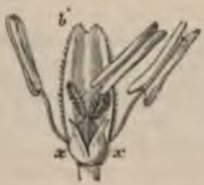


Fig. 449.

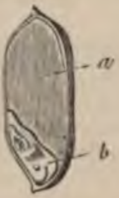


Fig. 450.

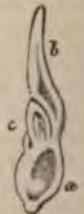


Fig. 448. Floret of *Avena* with outer palea removed: $b'$, inner palea; $x$, $x$, lodiculæ.
Fig 449. Section of caryopsis of *Triticum*: $a$, endosperm; $b$, embryo.
Fig. 450. Section of embryo of *Avena*, the endosperm removed: $a$, radicle; $b$, cotyledon; $c$, plumule.

*Stamens* hypogynous, 1–4, or 6 or more, 1 opposite the outer palea (alternate with the 2 scales); filaments capillary; *anthers* versatile.

*Ovary* superior, 1-celled, with one ascending ovule; *styles* 2 or 3, rarely confluent; *stigmas* feathery or hairy (figs. 257 & 258).

*Fruit* a caryopsis, with an inseparable pericarp; embryo lying on one side, at the base, of farinaceous albumen (fig. 449), sometimes with a second, small outer cotyledon alternate with the first.

### ILLUSTRATIVE GENERA.

Tribe 1. PANICEÆ. *Spikelets articulated closely below the lowest glume, 2-, very rarely 3-flowered; upper glume always containing the most perfect and only fertile flower; axis of spikelet never produced beyond the lower palea; lodicles never more than 2.*

Panicum, *L.*
Setaria, *L.*
Sorghum, *Pers.*
Andropogon, *L.*
Coix, *L.*

Tribe 2. PHALARIDEÆ. *Spikelets articulated, sometimes as in* Paniceæ, *and sometimes at the base of the pedicels near the main axis, 3- or apparently 1-flowered; outer empty glumes laterally compressed, often united at the base, longer than the rest; lower palea terminal, hairy, with 2 rudimentary glumes below it: otherwise as in* Paniceæ.

Phalaris, *L.*

Tribe 3. POACEÆ. *Spikelets usually articulated above the lowest glume, 1- or many-flowered; lowest flower usually perfect, terminal flower very rarely more perfect than those below it; axis of the spikelet almost invariably terminated by an imperfect glume, which is frequently reduced to a small point or bristle; lodicles generally 2, sometimes 3; stamens 1–3, rarely 6; fruit always shorter than the lower palea.*

Agrostis, *L.*
Stipa, *L.*
Oryza, *L.*
Chloris, *Sw.*
Avena, *L.*
Festuca, *L.*
Bromus, *L.*
Bambusa, *L.*
Hordeum, *L.*
Triticum, *L.*

**Affinities.**—The tribes above mentioned are those adopted by General Munro, the leading authority on this immense and difficult family. The description of the Grass-inflorescence above given is in accordance with the views of R. Brown, generally accepted in this country, although questioned by Bentham and some foreign botanists. The following are some of the principal arguments in its favour. Taking the alternation of 3-merous circles of organs as the rule in Monocotyledons, if we select a triandrous Grass, we find that the outer stamen stands between, *i. e.* alternates with the hypogynous scales; only two of these usually exist, but in *Stipa* and *Bambusa*, for example, a third occurs, and stands in front of the inner (double) pale; thus the scales (*lodiculæ*) must be regarded as representing the petals, of which the inner one is usually suppressed, and the other two approximated or coherent, in accordance with the law affecting the next circle; for when Monocotyledonous flowers are truly monochlamydeous, and this condition arises from the suppression of the corolline or inner whorl, the stamens stand *opposite* the parts of the perianth. Outside the *lodiculæ* we find the 2 pales or *glumellæ*. The outer one is opposite the outer stamen of triandrous flowers, and the 2 inner stamens are opposite the 2 primary veins of the inner pale; and since, moreover, this generally exhibits a double character, its construction from the confluence of 2 sepals is no great assumption, especially when we see the 2 *lodiculæ* confluent, as in *Melica* and *Glyceria*. In diandrous Grasses (*Anthoxanthum*) the outer stamen is wanting; in most Grasses the inner petal (*lodicula*) is absent; the inner (double) pale is absent in *Alopecurus*, *Panicum*, &c; in *Lolium* and *Lepturus* the outer glume is absent; in addition to which the few-flowered spikelets of very many genera contain abortive, unisexual, or neuter florets, consisting of rudimentary pales.

Other authors, as has been noticed, object to the explanation of the flower we have given, and regard the outer pale as a bract in the axil of which the floral axis arises; Link even looked upon the *lodiculæ* as analogous to the scales in the throat of *Narcissus*, therefore apparently as representing the *ligules* of metamorphosed Grass-leaves. The remarkable awn which is produced on the outer pale of many Grasses, more or less free from its lamina, is regarded by some authors as a barren development of the axis of the spikelet, which would make the inner pale the subtending bract of the flower. And it has been considered that the occasional appearance of a flower on the upper part of the outer pale of monstrous flowers of the Nepal Barley (*Hordeum cœleste*) also indicates the pale to be a bract with an abortive floral axis adherent to it; in which case the inner pale would certainly be the bract subtending the flower composed of *lodiculæ*, stamens, and ovary. This perhaps derives some support from the structure of the spathe in *Pistia*; but the whole is more simply explained as an irregular monstrosity, since the outer pale of viviparous Grasses (*i. e.* plants with the spikelets developing tufts of leaves) often appears as a rudimentary leaf with ligular processes at the junction of the vaginal and laminar regions, and thus as a simple leaf; and the only remaining ground for regarding it as a bract, rather than the outer sepal, is the fact of the inner pale being inserted a little higher up in the rachis.

The ligule has been considered an adnate stipule; it seems more simple to regard it as an excrescence from the upper part of the sheathing petiole.

The above explanation of the structure of this Order brings them into direct relation with the general body of Monocotyledons; and the stems of *Bambusa* have the habit even of some Palmaceæ, while the structure of the seed approaches that of Araceæ. But the nearest allies, in both habit and structure, are of course the Cyperaceæ: one distinctive mark between them, the hollow stem, suffers exception in *Saccharum* and various Grasses of hot climates; the creeping rhizomes of ordinary Grasses are commonly solid. The supposed diversity of structure of the stem of Grasses from that of other Monocotyledons is imaginary; their culms are simply fistular states of the structure existing in *Tradescantia virginica*, which, like Grass-stems, roots freely at the nodes. The habit of the Grasses familiar to us in Britain is uniformly herbaceous; but *Saccharum*, and some southern forms, such as *Panicum spectabile*, *Festuca flabellata*, &c., attain the dimensions at least of shrubs; and *Bambusa* is arborescent, having a woody stem 50 or 60 feet or more in height.

**Distribution.**—Constituting one of the largest natural Orders, the Grasses are universally distributed, and in temperate climates appear in vast numbers of individuals, forming the principal mass of the verdure covering the surface of all but utterly barren soil. The great extent of their cultivation is also remarkable, and still more the absence of information as to the native countries of the Grain-grasses, which have been objects of artificial culture from before the memory of man. Rye, Barley, and Oats are the harder grains; Wheat is the chief grain of temperate and warm temperate climates, being associated in the latter with Maize and Rice, which form the chief grains of the tropics,—Maize more particularly in

America, Rice in Asia, and both, locally, in Africa, Rice-growing being dependent upon the possibility of irrigation. Various Millets (*Sorghum, Panicum*, &c.) are largely grown in Africa and Asia, and to some extent in South Europe.

The Grasses of warmer climates are more tufted and less gregarious in growth, acquire greater stature, are sometimes arborescent, and very frequently present the monœcious or polygamous condition of the flowers.

**Qualities and Uses.**—The main value of this Order rests upon the seeds, or more properly the fruits, especially of what are called the "Cereal Grains," just referred to, and which, in their abundant farinaceous albumen, capable of great improvement in quantity and quality under cultivation, furnish the principal material for bread in most countries, except where the severe cold forbids their growth, or the fertile soil and favourable climate supply sufficient food with a less laborious agriculture, as in the case of the Plantain, Bread-fruit, and other tropical esculents. The Sugar-Cane is another grass of scarcely less value; and the fodder-Grasses are of immense importance, as furnishing food to domestic animals. A few of the Grasses have somewhat active properties.

The principal Corn-plants are:—Wheat, *Triticum vulgare* and many varieties (Spring Wheat is called *T. æstivum*, Autumn Wheat *T. hibernum*); *T. Spelta*, Spelt; *T. compositum*, the Mummy or Egyptian Wheat, has compound spikes; Barley, *Hordeum distichum*, with its varieties *Hordeum vulgare* (Bere or Big) and *H. hexastichum*; Oats, *Avena sativa* and *A. orientalis* (Tartarian Oats); Rye, *Secale cereale*; Maize or Indian Corn, *Zea Mays*; and Rice, *Oryza sativa*.

Among those less generally known are:—several Millets, such as *Setaria germanica* (German Millet); *Setaria italica* ("Kora Kang," East Indies); *Panicum frumentaceum* ("Shamoola," Deccan); *Andropogon Sorghum* ("Durra") and *A. saccharatum* ("Shaloo," East Indies); *Panicum miliaceum* ("Warree," East Indies); *Penicillaria spicata* ("Bajree," East Indies); *Paspalum exile* ("Fundunji," West Africa); *Poa abyssinica* and *Eleusine Tocusso* ("Teff" and "Tocusso," Abyssinia); *Eleusine Corocana* ("Natchnee," Coromandel); *Zizania aquatica*, Canada Rice; *Phalaris canariensis*, Canary-seed, &c. &c.

Among the most valuable fodder-Grasses of temperate climates are:—the Rye-grasses, *Lolium perenne, italicum*, &c.; *Phleum pratense, Festuca pratensis, Cynosurus cristatus, Anthoxanthum odoratum*, &c. *Panicum spectabile*, a hay-grass of Brazil, grows 6 or 7 feet high; *Anthistiria australis* is the "Kangaroo Grass" of Australia; *Anthistiria ciliata* and *Cynodon Dactylon* are esteemed Indian fodder-grasses; *Tripsacum dactyloides*, Gama-grass, in Mexico; *Gynerium argenteum* is the Pampas-grass; and *Festuca flabelloides*, the Tussac-grass of the Falkland Islands, is said to be very nutritious.

*Saccharum officinarum* is the Sugar-Cane; *Sorghum saccharatum* and *Gynerium saccharoides* (Brazil) likewise contain much sugar, as does also Maize, before the grain is ripened. Many Grasses are fragrant; the Sweet Vernal-grass of our meadows, *Anthoxanthum odoratum*, is an example, the scent being most powerful in dried grass; *Hierochloë borealis* is another: and this quality is still more strongly developed in some East-Indian species, such as *Andropogon citratum* ("Lemon-grass") and *A. Iwarancusa*, *A. Calamus-aromaticus*, and *A. muricatum* ("Vetivert"), of which the roots are largely used. This last Grass has stimulating properties; and another species, *A. Nardus*, is called "Ginger-grass," from its pungency. Many others were formerly, or are still locally, esteemed as medicinal, such as:—*Coix Lachryma*, the hard grains of which are known by the name of "Job's Tears;" the common Reeds, *Phragmites arundinacea, Calamagrostis, Arundo Donax, Triticum repens*, (Couch Grass or Quitch of farmers), &c. The supposed poisonous property of Darnel (*Lolium temulentum*) is not satisfactorily ascertained. Among the Grasses useful in manufactures are the Bamboo (*Bambusa arundinacea*), the Reed, *Phragmites, Donax*, &c. Coarse paper has long been made from the Bamboo in India, and recently from various straws in this country. *Lygeum spartum* is the Esparto Grass, much used as a coarse fibrous material, and also in the manufacture of paper. The Sand-grasses, *Elymus arenarius, Arundo arenaria*, and similar creeping species, are valuable binding-weeds on shifting sandy shores. Grasses are remarkable for the quantity of silex existing in the epidermis; and in the Bamboo a solid siliceous substance, called Tabasheer, collects in the hollow joints above the nodes. Many species are cultivated for the elegance of their flowers or their foliage, such as *Arundo Donax*, various species of Bambusæ, *Gynerium* (the Pampas Grass), &c.

(ERIOCAULACEÆ are aquatic or marsh-herbs, stemless or short-stemmed, with a tuft of fibrous roots, and a cluster of linear, often loosely cellular, grass-like leaves, and naked scapes sheathed at the base, bearing dense heads of monœcious or rarely diœcious, small, 2–3-merous flowers, each in the axil of a scarious bract; the perianth double, or rarely simple, scarious; the anthers 2-celled, introrse; the fruit a 2–3-celled, 2–3-seeded capsule; seeds pendulous, winged or hairy, with a lenticular embryo at the end of the albumen remote from the hilum. The membranous tube surrounding the ovary represents the corolla, and thus places this Order intermediate between the Glumaceous Orders and the Xyridaceæ, which lead on through Commelynaceæ to the Liliaceæ and their allies. The plants are mostly natives of America and Australia. *Eriocaulon septangulare* occurs in the Western Islands of Scotland (Skye).)

(RESTIACEÆ are herbs or under-shrubs, with or without perfect leaves; stems usually with slit, equitant leaf-sheaths; with spiked or aggregated glumaceous, mostly unisexual flowers; glumes 2–6 or seldom 0; stamens 2–3, adherent to the inner glumes; anthers 1-celled; ovary 1–3-celled; ovule solitary in each cell, pendulous; seeds albuminous; embryo terminal. Principally distinguished from Cyperaceæ by the pendulous seed and terminal lenticular embryo, further also by the leaf-sheaths being slit; from the Juncaceæ by the same characters, by the stamens when 3 being opposite the inner glumes, and by the 1-celled anthers. They are without the membranous perianth between the glumes and the ovary which occurs in Eriocaulaceæ, while Xyridaceæ have the floral envelopes in 2 circles, of which the inner is petaloid. From Desvauxiaceæ they differ in having 2 or 3 stamens, and if with a 1-celled ovary usually 2 styles, and the distinct perianth. The species occur chiefly in Australia and South Africa; one occurs in Chili. The tough, wiry stems have economic uses, for basket-making, thatching, &c. Genera: *Restio*, L.; *Thamnochortus*, Berg.; *Wildenovia*, L.)

(**Desvauxiaceæ** are little sedge-like herbs, with glumaceous flowers in a terminal spathe; glumes 1 or 2; paleæ 0, or represented by tender scales parallel with the glumes; ovaries usually several, sometimes consolidated, each with a pendulous ovule; stamens 1, or rarely 2; anthers 1-celled; seeds albuminous; embryo terminal. These little plants, chiefly natives of Australia, are of small importance, except as representing one of the types of the Glumaceous condition of Monocotyledons. They differ from Cyperaceæ in having several 1-celled ovaries more or less coherent, or, if a solitary ovary, it is 1-carpellary; the anthers also are 1-celled, and the embryo terminal, as in Restiaceæ: but they have only one stamen, a 1-celled ovary, and a utricular fruit bursting longitudinally. Genera: *Centrolepis*, Labill.; *Gaimardia*, Gaudich.)

## ORDER CLVIII. CYPERACEÆ. SEDGES.

*Class.* Glumaceæ, *Endl.* *All.* Glumales, *Lindl.* *Coh.* Glumales, *Benth. et Hook.*

521. *Diagnosis.*—Grass-like or rush-like herbs, with fibrous roots and solid stems, closed tubular leaf-sheaths, without ligules, and spiked, perfect or unisexual flowers, one in the axil of each of the glume-like imbricated bracts, destitute of any envelopes or with a tubular perianth (figs. 452 & 453), or with hypogynous bristles or scales in its place (fig. 451); stamens definite, hypogynous, 1–7 or 10 or 12; anthers 2-celled; the 1-celled ovary with a single erect anatropous ovule forming in fruit a utriculus containing a seed with a lenticular embryo enclosed in the base of albumen.

Fig. 452.

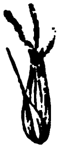


Fig. 451.

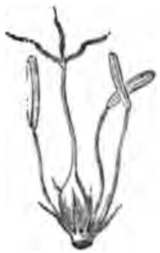


Fig. 453.

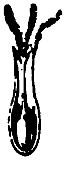


Fig. 451. Flower of *Eriophorum*. Fig. 452. Female flower of *Carex*. Fig. 453. Section of the same, showing the ovary.

ILLUSTRATIVE GENERA.

Carex, *Mich.*
Kobresia, *Willd.*
Schœnus, *L.*
Cladium, *R. Br.*
Isolepis, *R. Br.*
Scirpus, *L.*
Eleocharis, *R. Br.*
Eriophorum, *L.*
Cyperus, *L.*
Papyrus, *Willd.*

**Affinities.**—This large Order of Glumaceous plants resembles in many presects the Grasses, but has several marked distinctive characters, viz. the tubular leaf-sheaths, the usually angular and solid stems, the general reduction of the floral envelopes to a single bract or glume (2 additional glumes exist in *Carex* and some other genera, and hypogynous bristles or setæ in *Scirpus*, *Eriophorum*, &c.), and the fact of the embryo being enclosed centrally in the base of the albumen of the seed. From Restiaceæ, some of which resemble Sedges in habit, they are distinguished by the erect seeds, by the 1-celled ovary being formed of 2 or 3 carpels, and by the leaf-sheaths not being slit.

**Distribution.**—Universally diffused, especially in marshes and about running streams. *Carex* and *Scirpus* belong chiefly to cool climates, *Cyperus*, *Mariscus*, and others to warmer, while some appear ubiquitous. *Scirpus triqueter* is found in Europe, South America, and Australia.

**Qualities and Uses.**—The plants of this Order are generally devoid of active properties, and are less nutritious than the Grasses; but some have bitter and astringent properties, while others are regarded as diaphoretics. Several of them have some economic value. The rhizomes of *Cyperus longus* are astringent, those of *C. rotundus* contain an aromatic oil; the creeping stems of *Carex hirta*, *arenaria*, and other species have been used as substitutes for Sarsaparilla. The rhizomes of *Cyperus esculentus*, *C. bulbosus*, and some other plants of this Order, being tuberous and devoid of noxious properties, are used locally as articles of food. *Papyrus antiquorum*, a tall sedge, with a spongy pith, is celebrated as having furnished the ancients with a kind of paper, made by cutting the pith into laminæ, which were laid one upon another and pressed, thereby becoming glued together by their own sap. Its stem was, and is, also used for basket-making, mats, &c., like various *Scirpi* &c. The species of *Eriophorum*, the Cotton-grasses of our moorlands, produce a flock of cottony hairs around the fruit, sometimes used for stuffing cushions, &c. *Carex arenaria* (fig. 24) and *C. incurva*, growing on sandy sea-shores, are very efficient in binding the shifting sand.

## (PHANEROGAMIA, FLOWERING PLANTS.)

### Division II. Gymnospermia.

522. Flowering plants, with achlamydeous unisexual flowers arranged in cones, the male flowers consisting of antheriferous scales collected in deciduous cones, and the female either of open carpels (fig. 454, A), bearing naked ovules, standing in the axil of a bract, and arranged in persistent cones, or of naked terminal ovules surrounded by a few scales; seeds albuminous, with an enclosed embryo bearing 2 cotyledons, which are simple or divided into several lobes—a whorl of 4 or more cotyledons (fig. 454, E) according to some authors,—and with the radicle enclosed in a sheath (fig. 454, D).

Fig. 454.

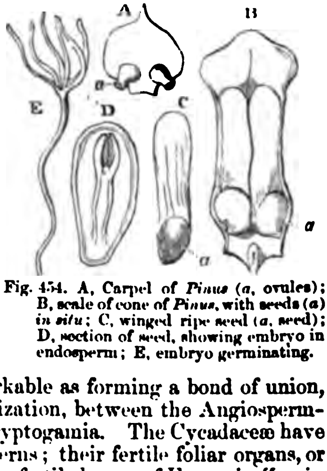


Fig. 454. A, Carpel of *Pinus* (*a*, ovules); B, scale of cone of *Pinus*, with seeds (*a*) *in situ*; C, winged ripe seed (*a*, seed); D, section of seed, showing embryo in endosperm; E, embryo germinating.

The members of this group are remarkable as forming a bond of union, in many important parts of their organization, between the Angiospermous Flowering plants and the higher Cryptogamia. The Cycadaceæ have the habit of Palms, or of Arborescent Ferns; their fertile foliar organs, or stamens and carpels, resemble in *Cycas* the fertile leaves of Ferns; in *Zamia*, as in Pinaceæ, the carpels approach nearer to the condition of the carpels of Angiosperms, but are flat or open. The structure of the female flower has been a subject of much controversy among botanists; the account above given is that which is on the whole the most generally adopted, though it should be stated that some botanists regard the outer investment of the ovule as an ovary, in which latter case the scale supporting it would have more of the nature of a branch than of a foliar organ. The reasons for considering the reproductive bodies as naked ovules and not ovaries are thus given by Alph. de Candolle:—1, the mode of development is centrifugal as in ovules, not centripetal as in ovaries; 2, the seeds of some Conifers (*Podocarpus*) are anatropal, a position unknown in ovaries; 3, the insertion is that of an ovule and not of an ovary. To this it may be added that the structure and arrangement of the tissues in the scale supporting the ovules are more akin to those of a leaf than to those of a branch. Anatomical investigation shows that while in Cycads the ovules are borne on the sides of a scale originating directly from the axis, in Conifers the ovuligerous scale is the production of an abortive secondary branch originating in the axil of the primary scale. Pinaceæ and Taxaceæ agree with Dicotyledons in habit; but the foliage of the latter approaches that of Ferns, while there are relations between their inflorescence and that of the Lycopodiaceæ; Gnetaceæ approximate to Casuarinaceæ and Chloranthaceæ in habit; and perhaps *Ephedra* may be compared with *Equisetum*. In all cases there may be observed a remarkable series of phenomena interposed between the arrival of the pollen upon the nucleus and the maturation of the embryo, not met with in Angiospermous Flowering plants, and, at the same time, very nearly allied to processes which take place in the germination of the spores of *Selaginella* and the Marsileaceæ. These will be more fully explained in the physiological portion of this work.

## ORDER CLIX. PINACEÆ. THE PINE ORDER.

*Class.* Coniferæ, *Endl.* *Class.* Gymnogens, *Lindl.* *Subclass.* Gymnospermeæ, *Benth. et Hook.*

523. *Diagnosis.*—Trees or shrubs, mostly with evergreen, linear, needle-like or lanceolate leaves, sometimes tufted, sometimes imbricated, monœcious or diœcious; the female flowers in cones, consisting of imbricated carpels arising from the axils of membranous bracts, and bearing (fig. 454, A) 2 or more ovules on the upper face; fruit a woody cone or a succulent berry formed by coherence of a few fleshy scales (*galbulus*).

ILLUSTRATIVE GENERA.

| Suborder 1. ABIETINEÆ. *Ovules with the micropyle next the base of the carpel; pollen oval.* | Subord. 2. CUPRESSINEÆ. *Ovules erect; pollen spheroidal.* |
|---|---|
| Pinus, *L.* | Juniperus, *L.* |
| Abies, *Tournef.* | Thuja, *Tournef.* |
| Araucaria, *Juss.* | Cryptomeria, *Don.* |
| | Cupressus, *Tournef.* |
| | Taxodium, *L. C. Rich.* |

**Affinities.**—The above diagnosis gives the essential character of this Order, which, however, deserves a little detailed notice, on account of the modifications occurring in the different genera, as well as on account of the difficulties which the structure of the inflorescence may present to the student.

Among the *Abietineæ*, in the common Scotch Fir (*Pinus sylvestris*) the male inflorescence appears in the form of a compound spike, each branch of which consists of a number of anthers arranged in a cone; each anther is represented simply by a scale having 2 parallel pollen-cells, one upon each side of a connective which is produced into a little tongue beyond the pollen-cells. The female inflorescence consists of a single cone, composed of single carpellary scales, seated each in the axil of a membranous bract, the whole spirally arranged round the axis; each carpel possessing, on the upper face, at the base, 2 naked ovules, with their points directed towards the base of the carpel. In other *Abietineæ* the stamens are more complex: in *Cunninghamia* the anther is 3-celled; in *Araucaria* many-celled, the *loculi* consisting of free tubular bodies attached by their apices to a thickened connective at the upper end of a slender filament; the condition of the carpels also varies, *Araucaria* and *Dammara* having but 1 ovule, *Cunninghamia* 3, and other genera more. A diversity also appears in the cones, from the different ways in which the carpels are developed: in *Pinus sylvestris*, and many others, the upper ends become thickened into woody heads (*apophyses*) meeting in a valvate manner, forming the "tessellæ" of the continuous surface of the unopened cone, while in *Abies*, *Cunninghamia*, &c. the upper ends of the ripe carpels overlap in an imbricated manner.

In *Cupressineæ*, the stamens of *Cupressus*, *Juniperus*, *Thuja*, &c. are peltate, with several loculi under the overhanging connective; and the carpels representing the female flowers have in *Thuja* 2 ovules, in *Cupressus* many, in *Juniperus* 2 or only 1 erect ovule at the base; in *Juniperus* the carpels ripen into fleshy structures, cohering together so as to form a kind of berry; in *Callitris* the cone is of globose form, and composed of 4 peltate scales, the *apophyses* of which meet in a valvate manner; the same is the case with a greater number of valves in *Cupressus*, while *Thuja* has the scales more distinctly imbricated, but still with thickened apophyses, which meet in a valvate manner (like those of *Pinus sylvestris*).

The curious fasciculate arrangements of the leaves of *Pinus* (§ 64), where 2, 3, 4 or more occur together, with a common membranous sheath at the base, offer valuable distinctive characters for the species. The affinities of the Pinaceæ are with Dicotyledons by their habit of growth, although there is an essential difference in the internal structure of their organs; the inflorescence of this and the associated Orders is perhaps more highly organized than that of the Cycadaceæ, and is connected with Phanerogamia, on the one hand, by the presence of distinct stamens and carpels, the latter producing a perfect seed; while the nature of the processes taking place in the development of the embryo (described in the Physiological Part of this work) indicates a close approach to the conditions which are met with in the higher Cryptogamia, especially *Selaginella*.

**Distribution.**—A considerable Order even in point of numbers, its representatives are met with in all parts of the world, the species of *Pinus*, *Abies*, and *Taxodium* growing socially, form characteristic forests in the northern hemisphere.

**Qualities and Uses.**—Most valuable as timber trees and as sources of important resins (turpentine, pitch, &c.) used in the arts, and aromatic oils and balsams having medicinal properties.

*Pinus* includes:—*P. sylvestris*, the Scotch Fir (North Europe); *P. Pinaster*, the Cluster-pine, a less hardy tree; *P. palustris*, the Swamp-pine of Virginia; *P. Tæda*, the Frankincense-pine. *Pinus Fremontiana*, *P. Lambertiana*, *P. Strobus*, &c. are other very valuable timber-trees, attaining a height of upwards of 200 feet. *Pinus Pinea*, the Stone-pine of the south of Europe, has edible seeds. *Abies* includes:—the Norway Spruce, *A. excelsa*; the Silver Fir, *A. pectinata*; *Abies balsamea*, Balsam-of-Gilead Fir, and *A. canadensis*, Hemlock Spruce, both North-American. *Cedrus*, a subgenus of *Abies*, includes the Cedar of Lebanon (*Abies Cedrus* or *C. Libani*), and the Deodar (*C. Deodara*), which is supposed to be merely a variety of the last named; *Larix*, another subgenus, includes the European (*Abies Larix* or *Larix europæa*) and other Larches, characterized by deciduous foliage; *Araucaria* includes the enormous Chilian Pine, *A. imbricata*, and the Moreton-Bay Pine, *A. Bidwilli*. *Eutassa excelsa* is the celebrated Norfolk-Island Pine. *Dammara australis* is the Cowrie Pine of New Zealand; *D. orientalis* the Dammar Pine of India. *Sequoia* (or *Wellingtonia*) *gigantea* is a Californian Pine, attaining a height of 300 feet; *Microcachrys tetragona* is the Huon Pine of Tasmania.

*Juniperus* is best known in this country by the common Juniper shrub, *J. vulgaris*, or by the cultivated Savine, *J. Sabina*; but the species of other countries are more important, as *J. bermudiana* and *J. virginiana*, the "Red Cedars," the aromatic wood of which is used for cabinet-making, and for blacklead pencils; *J. Oxycedrus*, a Mediterranean species, forms also good and durable wood. *Thuja occidentalis* and *orientalis* are the Arbor-vitæ trees of our shrubberies; *Cryptomeria* is now introduced also from Japan; *Cupressus sempervirens* is the common Cypress; *Callitris quadrivalvis*, the Arar-tree of North Africa, has odoriferous and durable wood; *C. australis*, is the Oyster-Bay Pine of Australia. *Taxodium distichum* is the Deciduous Cypress of the United States, and characterizes the Cypress-swamps of the Southern States.

Among the above, turpentine, resin, and pitch are derived from many; important kinds of resin are:—common turpentine, resin, pitch, and Burgundy pitch, from *Pinus sylvestris*; Venice turpentine from the Larch; Strasburg turpentine from *Abies pectinata*; Bordeaux turpentine from *P. Pinaster* &c.; Canada Balsam from *Abies balsamea* and *A. canadensis*; Sandarac from *Callitris quadrivalvis*; Gum-Dammar from *Dammara australis* &c. The berries of *Juniperus vulgaris* are aromatic, and are used for flavouring gin; they are diuretic; *J. Sabina* has still more active diuretic properties; and *Cupressus* and *Thuja* appear to have poisonous qualities. The large seeds of many other Pines, besides the Stone-pine, are eaten locally, in a fresh state, as of *Araucaria imbricata*, *A. Bidwilli*, &c.

## ORDER CLX. TAXACEÆ. THE YEW ORDER.

*Class.* Coniferæ, *Endl.* *Class.* Gymnogens, *Lindl.*

524. *Diagnosis.*—Trees or shrubs with narrow rigid leaves or broad leaves with forked nerves, unisexual naked flowers, surrounded by imbricated bracts, the male several together, composed each of one or several coherent anthers, the female of a solitary naked ovule, terminal or in the axil of a bract; the seed usually surrounded by a succulent coat.

### ILLUSTRATIVE GENERA.

| | | |
|---|---|---|
| Taxus, *L.* | Dacrydium, *Sol.* | Cephalotaxus, *Zucc.* |
| Podocarpus, *L'Hér.* | Phyllocladus, *L. C. Rich.* | Salisburia, *Sm.* |

**Affinities.**—The relations of this group, sometimes regarded as a Suborder of the Pinaceæ, are the same as those of that order; and from it these plants differ chiefly in the solitary ovule that replaces the cone. The leaves of *Salisburia*, and in a less degree those of other genera, are very similar to those of Ferns; and the stamens of *Taxus* closely resemble the sporanges of *Equisetum*.

**Distribution.**—A small group, the members of which inhabit temperate regions generally, or mountains in the tropics.

**Qualities and Uses.**—Agreeing in general with Pinaceæ, *Podocarpus*, *Dacrydium*, *Taxus* (Yew), &c. yield valuable timber. The leaves of the Yew are poisonous; but the pulp of the berries does not appear to share this property. The fruits of *Salisburia adiantifolia* are resinous and astringent.

## ORDER CLXI. GNETACEÆ.

*Class.* Coniferæ, *Endl.* *Class.* Gymnogens, *Lindl.*

525. *Diagnosis.*—Small trees or shrubs with jointed stems, opposite, simple netted-ribbed or minute and scale-like leaves, and unisexual (rarely hermaphrodite) flowers in catkins or heads; anthers 2-3-celled, opening by pores; female flower naked, or with two more or less combined scales, surrounding 1 or 2 naked ovules: seed succulent; embryo with 2 cotyledons, in the axis of fleshy albumen.

### ILLUSTRATIVE GENERA.

Ephedra, *L.* | Gnetum, *L.* | Welwitschia, *Hook. f.*

**Affinities.**—This Order is chiefly interesting as furnishing a link to connect the Coniferæ with the Dicotyledons, since the plants have a truly Gymnospermous organization of the flower, while in general structure *Ephedra* approaches to *Casuarina*, and *Gnetum* to *Chloranthus*. They are destitute of the resin so characteristic of Conifers. The ovule presents the curious peculiarity that a third integument, immediately investing the nucleus, grows out into a long process like a style, and which projects from the foramen of the outer coat. *Welwitschia mirabilis*, a native of desert regions in south-western Tropical Africa, where it was discovered by the botanist whose name it bears, is, in many respects, the most interesting flowering plant now in existence. It consists of a woody trunk, about 2 feet high, with a long woody root, and terminating above in an irregularly lobed saddle-like mass, 4–5 feet in diameter. From a groove beneath the edge of this is given off, on each side, a broad leathery leaf, some 6 feet long, and split into numerous thongs. These leaves are supposed to be the persistent cotyledons; and no others are produced, though the plant attains an age of at least a hundred years, and probably more. The disk at the top of the stem is marked by concentric lines. The inflorescence consists of cones borne on forked branches which originate from the edge of the disk. The cones contain, some female flowers, others male flowers; the latter with an abortive ovule occupying the extremity of the axis. The female flower is similar in essentials to that of *Gnetum*; the male is quite distinct from any thing else. It consists of a perianth, as in the male flowers of *Ephedra*, enclosing six stamens, united by their filaments into a short tube, and bearing globose anthers, which open by a 3-rayed chink. In the centre of the flower is a body like an ovary, with a terminal style-like prolongation and an expanded stigma. This pistil-like structure invests the nucleus of the ovule, which, in this case, is destitute of embryo-sac and embryo. The ovary-like body in this flower is shown, from its mode of development and structure, to be homologous with the coat of an ovule, and not to possess the characteristics of an ovary, except so far as superficial resemblance is concerned.

Fig. 455.

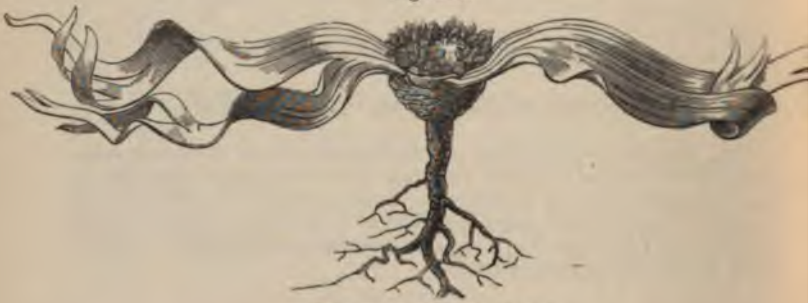


Fig. 455. *Welwitschia mirabilis.*

The long styliform process is similar to that which occurs in the ovule of *Ephedra*. The ovule, then, of *Welwitschia* is strictly Gymnospermous, like those of Coniferæ. The structure of the stem belongs to the Dicotyledonous type, but having, in addition to the other bundles, scattered vessels passing through the parenchyma, as in Monocotyledonous stems. Among the ordinary parenchymatous cells occur "spicular" cells of large size and irregular branching form; these are covered on the outside with rhomboidal crystals of carbonate of lime. Similar cells occur in *Araucaria.*

**Distribution.**—*Ephedra* occurs in Europe, Asia, and South America, in temperate regions; *Gnetum* in tropical India and in Guiana.

**Qualities and Uses.**—Unimportant; the branches and flowers of some *Ephedræ* were formerly used as a styptic drug.

## ORDER CLXII. CYCADACEÆ.

*Class.* Zamiæ, *Endl.* *Class.* Gymnogens, *Lindl.* *Subclass.* Gymnospermeæ, *Benth. et Hook.*

526. *Diagnosis.*—Palm-like, dwarf trees with simple trunks, having the internodes undeveloped, the surface tessellated with the scars of the fallen leaves; leaves clustered at the summit, pinnate, parallel-ribbed, more or less hard and woody, circinate in vernation; diœcious, the flowers in cones; the anthers covering the under surface of the male cone-scales; female flowers either peltate

scales with ovules beneath, or flat scales with ovules at the base, or somewhat leaf-like scales with the ovules on the margins; seeds with a hard or succulent coat, containing 1 embryo or several, in fleshy or mealy albumen.

ILLUSTRATIVE GENERA.

Cycas, *L.*
Dion, *Lindl.*
Zamia, *L.*
Encephalartos, *Lehm.*
Macrozamia, *Miq.*
Stangeria, *Moore.*

**Affinities.**—With the habit and appearance of Palms, especially in the genus *Stangeria*, these plants agree with Pinaceæ in the essential peculiarities of the organization of their flowers and seeds, while the distribution of the reproductive organs over the leaf-like carpels and antheriferous scales in *Cycas*, together with the circinate vernation, connect this Order with the Ferns, thus strengthening the relation between the Gymnospermia and the higher Cryptogamia, which is so evident in the affinities between Pinaceæ and Lycopodiaceæ. Some difference exists in the condition of the reproductive organs. The flower-cones, composed of imbricated scales, appear to be axillary productions in *Zamia*; but in *Cycas* they are formed from the terminal bud, which subsequently grows on (as in the Pine-apple), so that here the terminal inflorescence does not arrest the growth of the axis: the formation of cones occurs at intervals; and when the scales fall off after the pollen or the seeds are mature, the stem is found marked alternately with bands of scars of two kinds, those of the true leaves and those of the floral leaves (carpels and stamens). In *Zamia* the cones are lateral, like the spadices of many Palms. In *Cycas* the female cones are formed of large flat leafy carpels, with ovules arranged at some distance apart on the margins; the male cones are likewise formed of leafy scales, bearing numerous anthers (or loculi) scattered over the lower surface, the loculi being commonly grouped in fours like the sporanges of *Mertensia*. In *Zamia* the cones more nearly resemble those of Pinaceæ; the male cones are formed of peltate scales (with an apophysis as in the ripe cones of *Cupressus*) with the pollen-cases under the overhanging head; the female cones are composed of somewhat peltate scales bearing only a pair of ovules at the base.

**Distribution.**—Tropical and temperate parts of Asia and America; Africa, especially near the Cape of Good Hope, Madagascar, and Australia.

**Qualities and Uses.**—The chief value of these plants is as sources of a kind of Arrow-root or Sago, consisting of the starch washed from the internal parenchyma of the trunks, or obtained from the mealy albumen of the seeds. *Cycas revoluta* and *C. circinalis* are "Sago" plants in Japan and the Moluccas; various species of *Encephalartos* form what is called "Caffer-bread" at the Cape; *Dion edule* (seeds) furnishes a kind of Arrow-root in Mexico.

## SUBKINGDOM II. **CRYPTOGAMIA, or FLOWERLESS PLANTS.**

527. Plants producing sexual organs, but neither stamens, pistils, nor seeds. Embryo simple, homogeneous, not divided into distinct organs, but consisting of a single cell.

The plants included under the above head are divided into a great number of subdivisions, which, although all connected together by the characters above cited, yet differ exceedingly in the minor details of their conformation (see p. 153, §§ 305 & 306), on which account it is desirable to treat of the morphological details of each group at greater length than in the case of the corresponding groups of Phanerogams. The functional peculiarities are likewise separately treated in the physiological portion of this work.

### DIVISION I. **Angiosporæ.**

528. Cryptogamous plants possessing true stems and leaves (fronds), producing their spores in "sporangia" or spore-cases, which are themselves sometimes enclosed within spore-fruits—"conceptacles or sporocarps." Antheridia producing spirally twisted, ciliated "antherozoids" or "spermatozoids." Spores, when germinating, producing a "prothallus," on which the "archegonia" or female organs are formed, which are fertilized by the antherozoids.

Angiosporous Cryptogams, as above defined, correspond for the most part to the Acrogens of other botanists. The woody tissue includes vascular as well as cellular elements, and increases chiefly by addition to the summit, as will be further explained under the head of Minute Anatomy and Physiology. The plants manifest in the germination of the spores a sort of alternation of generations: first a prothallus is developed, on which the true female organ is formed and fecundated by the antherozoids, which latter are either formed on the primary plant, or on the prothallus with the archegonia.

### CLASS I. SPOROGAMIA.

529. Angiosporous Cryptogams, producing two kinds of spores:—"microspores," containing spiral spermatozoids; and "macrospores," which in germinating form a "prothallus," and on which the archegonia are formed.

This class includes the Orders Marsileaceæ and Lycopodiaceæ, associated under this name on account of the similarity of their modes of reproduction. They produce spores of two kinds, called respectively macro- and microspores: the former give origin to the spore; the latter are "antheridia," in which are formed "antherozoids." The spore emits a "prothallus," on which is borne one or more archegones, analogous to ovaries and containing a cell which is fertilized by the antherozoids.

## ORDER CLXIII. MARSILEACEÆ.

*Class.* Hydropterides, *Endl.* *All.* Lycopodales, *Lindl.*

**530.** *Diagnosis.*—**Creeping or floating herbs, with an inconspicuous stem bearing stalked or sessile leaves, circinate in vernation; sporocarps stalked, situated at the base of the leaves or leaf-stalks, and 2–4-celled, 2–4-valved, containing antheridia (microspores) and sporangia in different compartments of the same fruit, or 1-celled with the antheridia and sporangia in separate sporocarps, and springing from a central placenta; spore producing a prothallus, on which are one or more archegonia.**

The Marsileaceæ, of which *Pilularia* is our only native example, are small herbaceous plants, growing in the mud at the margins of ponds, or floating in stagnant pools. Their stem is little developed, consisting in the terrestrial forms of a slender creeping rhizome with tufts of filiform adventitious roots; in the aquatic forms it is a mere basis for the tufts of leaves. The leaves are small, filiform in *Pilularia*, ovate in *Salvinia*, and of remarkable quaternate form in *Marsilea*. The fruits consist of capsules of globular or oval form (*sporocarps*, *conceptacles*, or *spore-fruits*), borne on stalks which arise at the bases of the leaves or leaf-stalks. In *Pilularia* and *Marsilea* the *spore-fruits* are divided into chambers, which contain the two kinds of spores in distinct sac-like cases (*thecæ*). In *Pilularia* the sporocarp bursts into two or four valves, and liberates a mucilaginous substance in which are intermixed the micro- and macrospores. In *Marsilea* the sporocarp bursts in a similar manner to give exit to a mucous thread or stalk, bearing oblong sporanges or spore-cases, some of which contain large, others small spores. In *Salvinia* and *Azolla*, the spore-fruits are of two kinds, and produce respectively antheridia and sporangia. The antheridia contain antherozoids like those of Ferns.

**Affinities, &c.**—The organization of the reproductive organs in this Order is the highest met with in Cryptogamia, the sporanges being enclosed in capsules stalked upon the main stem. *Salvinia* and *Azolla* are sometimes included in a distinct group, *Salviniecæ*, distinguished from the true Marsileaceæ in habit, in the circumstance that their reproductive organs occupy separate conceptacles, the conceptacle itself being 1-celled, with a central placenta, and destitute of the gelatinous body so characteristic of *Marsileas*. Moreover the prothallus bears more than one archegonium. The species are not very numerous, but are widely diffused, chiefly in temperate climates. They have no known properties. The Nardoo of Australia (*Marsilea salvatrix*) belongs to this family; its spores have been eaten in cases of scarcity.

## ORDER CLXIV. LYCOPODIACEÆ. CLUB-MOSSES.

*Class.* Selagines, *Endl.* *All.* Lycopodales, *Lindl.*

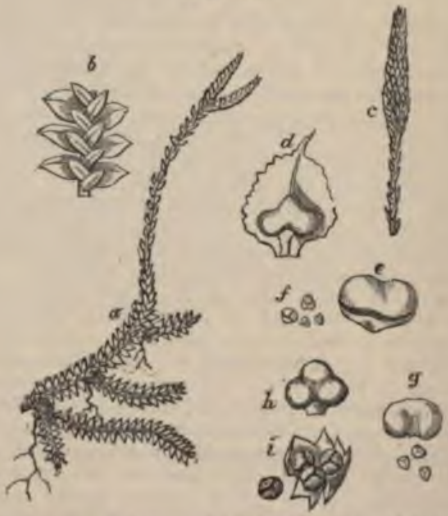
531. *Diagnosis.*—Herbaceous plants with creeping stems, branching in a bifurcate manner, clothed with small, usually closely imbricated leaves. Sporanges in the axils of more or less metamorphosed leaves, often arranged in cone-like spikes (stalked or sessile) formed from one of the branches of a bifurcation of the stem; sporanges 1–3-celled, of two kinds (*Selaginella*), producing either 4 large ovulary spores or numerous small antheridial spores.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Tmesipteris, *Bernh.* | Lycopodium, *L.* |
| Psilotum, *Sw.* | Selaginella, *Spring.* |

The Lycopodiaceæ, including the *Lycopodieæ* and also the *Isoëteæ*, are distinguished by their sporanges being sessile in the axils of leaves or bracts, which are often collected into a kind of inflorescence like the cone of Firs.

Fig. 456.



Organization of Lycopodieæ:—*a*, fragment of *Selaginella helvetica*, with fruit-spikes; *b*, a portion of the leafy stem; *c*, fruit-spike of *Lycopodium annotinum*; *d*, fruit-scale of *L. inundatum*, with axillary sporange; *e*, the sporange bursting; *f*, spores from *e*: *g*, sporange and small spores; *h*, sporange with quaternary large spores; and *i*, the same, burst; all from *Selaginella helvetica*.

The *Lycopodieæ* have slender stems characterized by a bifurcating mode of ramification (fig. 456, *a*). In the *Lycopodia* the stems are hard and woody, in the *Selaginellæ* usually very delicate. They produce solitary adventitious roots at the forks, and are covered with small imbricated leaves, all alike and arranged spirally in *Lycopodium*, but of two kinds and arranged in peculiar vertical rows, giving a flattened aspect to the stem, in *Selaginella* (fig. 456, *b*); the smaller leaves here are regarded by some authors as stipules.

The fertile leaves of many *Lycopodia* and *Selaginellæ* are collected in slender-stalked or sessile cones or strobiles (fig. 456, *c*). The ***spores*** are contained in depressed oval cases, seated in the axils of these leaves (*d*); and in *Lycopodium* only one kind, containing a large number of spores, resembling pollen-grains, has been found (*e*, *f*); in *Selaginella*, however, microspores or antheridia are formed, and the lowest bract in each cone is found to subtend a sporange containing four much larger spores (macrospores) (*h*, *i*); these last are the kind which germinate and reproduce the plant, producing in the first instance a prothallus, on which archegonia are produced and are fertilized by antherozoids like those of Ferns and formed within the microspores. The reproduction of *Lycopodium* has not been observed.

*Lycopodieæ* seem to have attained far greater dimensions in former ages; the fossil trunks of trees called *Lepidodendra* appear to have belonged to plants of this family, and which must have rivalled the arborescent Ferns. At present they are herbaceous plants, the hardy *Lycopodia* mostly creeping on the ground, the more delicate *Selaginellæ* either creeping or climbing over low objects, in damp and warm climates.

**Affinities, &c.**—The immediate relations of this Order are with Isoëtaceæ, which scarcely differ, except in the organization of the vegetative structure, and in the larger number of the macrospores. A most distinct affinity exists with Pinaceæ in the cone-like spikes, as well as the development of the embryo in the larger spores. The Club-mosses are generally diffused:—the species of *Lycopodium* in temperate and cold climates; the *Selaginellæ* in warm regions, being especially abundant and large in warm damp localities like the Indian islands. Some kinds are apparently dangerous or poisonous: *L. clavatum* has been used as an emetic; *L. Selago* and *L. catharticum* are purgatives; the latter is very violent in its action. The *Selaginellæ* are very elegant plants, much valued in cultivation, in association with Ferns, and in moist stoves on account of the bright and delicately formed foliage. One or two of the species roll up their fronds when dry, and unfold them again when placed in water, owing to the rapid absorption of the fluid, whence they have been called Resurrection plants.

## ORDER CLXV. ISOËTACEÆ. QUILL-WORTS.

*Class.* Selagines, *Endl.* *All.* Lycopodales, *Lindl.*

532. *Diagnosis.*—Tufted aquatic or marsh herbs, growing from a perennial corm-like stem, supporting linear cylindrical leaves of delicate texture, producing annually, in the axils of successive cycles of the leaves, sporanges which are immersed in the substance of the inner face of the leaf and divided internally into chambers by more or less perfect septa;

some of the sporanges produce small antheridial spores, others (fewer) large spores.

ILLUSTRATIVE GENERA.

Isoëtes, *L.* | ? Phylloglossum, *Kze.*

The *Isoëteæ* are represented by a genus of plants growing in the mud at the bottom of pools. Their stems consist of a kind of *corm*, of perennial duration and of woody structure when old, producing adventitious roots on the underside, like the corms of the Flowering plants, and sending up tufts of leaves from a single terminal bud. The leaves are very delicate, of cylindrical form, and contain longitudinal air-chambers; they are expanded into a kind of sheath, "phyllopod," at the base where attached to the corm; and in their axils, more or less imbedded in the substance, are the *sporanges*, sacs divided into several chambers, some filled with numerous small *pollen-like spores*, others containing a small number of *large spores*, resembling the quaternary spores of *Selaginella*, and, like them, producing the prothallus on which the archegonia or female organs are placed. The antherozoids are like those of Ferns.

**Affinities.**—Nearly related to Lycopodiaceæ, with which their reproductive organization agrees in all essential respects—but differing strikingly in habit, especially in the character of the stem, which is externally like a corm, but in reality is a perennial woody caudex increased in size by successive annual growths. *Phylloglossum* would appear to be exactly intermediate between *Isoëtes* and *Selaginella*, having the leaves and stem of the first, with a stalked spike, like the second: perhaps this and the last Order should be conjoined. The species of *Isoëtes* are generally diffused in the northern hemisphere. They have no known properties.

## CLASS II. THALLOGAMIA.

533. Angiosporous Flowerless plants producing spores of one kind in sporanges placed on the leaves or on the stem; the spore germinating into a green cellular prothallium (like a *Riccia*), on which are developed antheridia and archegonia, the latter giving origin to a leafy stem; antherozoids spiral.

This class comprises the Ferns and the *Equiseta*, or Horse-tails, two groups which are connected together by the phenomena presented in the germination of their spores, and by their producing these organs in one kind only. While the Sporogamia have what may be called male and female spores, the Ferns and Horse-tails are furnished with spores of only one kind, which germinate and produce an Algoid frond called a *prothallus*, upon which are developed the sexual organs, the *archegonia* and *antheridia*. When an archegonium is fertilized, it gives birth to a kind of embryo, which assumes the character of a bud, sends out leaves (or stems) and roots, and grows up into the form of the parent plant, while the germ-frond or *prothallus* dies away.

The Filices and the Equisetaceæ are very unlike in their fully developed conditions: in the former the leaves are the predominant organs; in the latter the leaves are almost abortive, and the stem is highly developed.

## ORDER CLXVI. EQUISETACEÆ. HORSE-TAILS.

*Class.* Calamariæ, *Endl.* *All.* Muscales, *Lindl.*

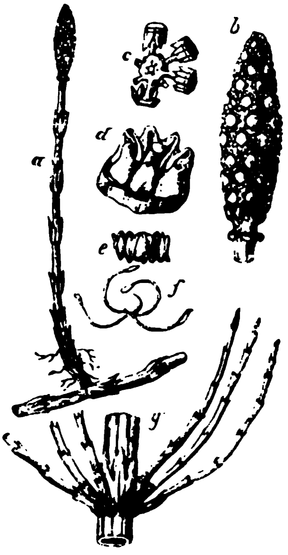
534. *Diagnosis.*—Herbaceous plants with slender, jointed, sometimes nodular, subterraneous rhizomes, sending up at intervals fistular jointed stems, bearing whorls of scales (leaves) at the joints, where they are sometimes verticillately branched; stems either barren or fertile, the latter terminating in a clavate joint covered with sporanges, consisting of peltate bodies (fig. 457, *c*, *d*) with dehiscent spore-chambers under the overhanging head. Spores of one kind, with 4 elastic filaments, "elaters," formed by the spiral fission of the outer coat of the spore (fig. 457, *e*, *f*).

### ILLUSTRATIVE GENUS.

### Equisetum, *L.*

The Equisetaceæ at present existing consist of a single genus, *Equisetum*, a small assemblage of herbaceous plants growing in marshy places, having a creeping, subterraneous, jointed, but solid rhizome (fig. 457, *a*), from which arise erect shoots or stems of peculiar aspect, and usually of greyish-green colour. They are striated longitudinally, jointed at intervals, with circles of small and narrow membranous scales, representing the leaves, at the joints (fig. 457, *a*, *g*), and they are fistular, like the stems of Grasses. They are, moreover, traversed by a number of air-canals varying in number and disposition in the several species. The stems are sometimes simple, sometimes compound, bearing whorls or branches at the nodes (*g*), which branches resemble the main stem in character, and frequently branch again in a similar manner at their nodes. The erect stems are either fertile or barren; in some species the fertile stems are short and simple, while the barren stems are tall and provided with numerous whorls of spreading compound branches (*E. fluviatile*). The fertile stems terminate in a kind of club or spike (fig. 457, *a*, *b*), composed of a short axis closely covered with *sporanges* (*c*);

Fig. 457.



Organization of Equisetaceæ:—*a*, fertile stem of *Equisetum arvense*, arising from the rhizome; *b*, fruit-spike (nat. size); *c*, transverse section of do., showing how the sporanges are attached to the axis; *d*, a sporange, seen from beneath; *e*, a spore; *f*, the same, with its "elaters" uncoiled; *g*, fragment of the branched stem of *E. palustre*.

these are little peltate or mushroom-shaped bodies (*c*, *d*), attached by their stalks to the central axis, and bearing under the overhanging head a circle of vertical tooth-like pouches (*d*), resembling the anther-cells of *Thuja*, and which burst by a vertical slit on the inside to emit the spores when ripe. The *spores* are furnished with remarkable filiform processes, called *elaters* (fig. 457, *e*, *f*), consisting of four short filaments attached at one side, coiled spirally round the spore before it is mature, and unwinding with elasticity when the spore is discharged from the sporange. The erect stems die to the ground annually, while the rhizome continues its growth by buds.

**Affinities, &c.**—The plants of this Order belong all to a single genus, which is very unlike any other form of Cryptogamous plants. In external appearance the stems have no little resemblance to those of *Ephedra* and *Casuarina*; but their internal organization is totally different. The spikes of sporanges also are very like the male cones of *Zamia* among the Gymnospermous Phanerogamia; but the spores of *Equisetum* are furnished with spiral filaments, forming a structure quite peculiar to the Order. In conjunction with the fistular erect stems, having a slight similarity to those of Grasses, we find in *Equisetum*, as in that Order, a deposit of silex in the epidermal tissues, and in *E. hyemale* so abundant that the ashes of the stem form a good polishing-powder, like fine tripoli. In the history of the development of their spores these plants agree essentially with the Ferns (see PHYSIOLOGY). The Equisetaceæ are found in wet places in most parts of the globe.

## ORDER CLXVII. FILICES. FERNS.

*Class.* Filices, *Endl.* *All.* Filicales, *Lindl.*

535. *Diagnosis.*—Herbs with a subterraneous rhizome, or trees with an unbranched caudex, with well-developed, generally more or less divided or compound leaves, circinate in vernation, and all or part of which bear clusters of sporanges (*sori*) upon the lower surface (fig. 458, *a*, *b*, *d*) or at the margins (*g*), seated upon branches of the veins. The sori are naked (*b*) or covered at first by a variously formed dehiscent or separating membranous structure (*indusium*, *d*, *e*) which is continuous with the epidermis of the leaf.

### ILLUSTRATIVE GENERA.

Tribe 1. POLYPODIEÆ. *Sporanges stalked, with a vertical annulus.*

Acrostichum, *L.*
Gymnogramma, *Desv.*
Ceterach, *Adans.*
Polypodium, *L.*
Adiantum, *L.*
Pteris, *L.*
Allosorus, *Bernh.*
Blechnum, *L.*
Asplenium, *L.*
Scolopendrium, *Smith.*
Lastræa, *Presl.*
Aspidium, *Swartz.*
Cystopteris, *Bernh.*

Tribe 2. CYATHEÆ. *Sporanges sessile, more or less elevated on a common receptacle: annulus vertical.*

Alsophila, *R. Br.*
Cyathea, *Smith.*

Tribe 3. PARKERIEÆ. *Sporanges thin, with a broad, imperfect, vertical annulus.*

Ceratopteris, *Brongn.*
Parkeria, *Hook.*

Tribe 4. HYMENOPHYLLEÆ. *Sporanges on an axis produced by the excurrence of a vein beyond the margin of the leaf; annulus horizontal or oblique.*

Hymenophyllum, *Smith.*
Trichomanes, *L.*

Tribe 5. GLEICHENIEÆ. *Sporanges commonly arranged in fours in the dorsal sori, nearly sessile, with a transverse or oblique annulus; bursting vertically on the inside.*

Gleichenia, *Smith.*
Mertensia, *Willd.*

Tribe 6. SCHIZÆEÆ. *Sporanges dorsal: the annulus in the form of a cap on the summit; dehiscence vertical.*

Schizæa, *Smith.*
Lygodium, *Swartz.*

Tribe 7. OSMUNDEÆ. *Sporanges stalked, dorsal, or arranged on pinnæ assuming a spiked or paniculate aspect from the absence of parenchyma between the veins; annulus incomplete, dorsal; dehiscence across the vertex.*

Osmunda, *L.*
Todea, *Willd.*

Tribe 8. MARATTIEÆ. *Sporanges free, closely packed in two rows, or in a circle, or soldered together so as to resemble a many-celled capsule, each cell opening by a pore; annulus none.*

Angiopteris, *Hoffm.*
Marattia, *Sm.*
Danæa, *Sm.*

Tribe 9. OPHIOGLOSSEÆ. *Leaves not circinate; sporanges 2-valved, on the sides of a spike or scape, which is simple or branched; annulus none.*

Ophioglossum, *L.*
Botrychium, *Swartz.*

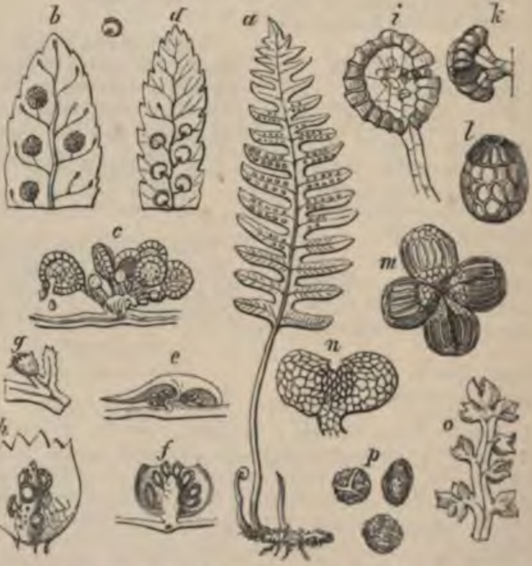
The Filices or Ferns exhibit a far greater variety of conditions than the Horse-tails. Their most remarkable character is the great development of the leaves, the stem being represented in most cases by rhizomes, although in some of the exotic forms it becomes a real trunk, rising above the ground in a manner analogous to the trunks of Palms (fig. 29).

The rhizomes of the herbaceous kinds are subterranean, and grow either horizontally or vertically. In the former the internodes are either developed or undeveloped; when they are developed, the leaves arise singly from the ground, as in the common Brake-fern (*Pteris*) and *Polypodium vulgare* (fig. 458, *a*); when the internodes are undeveloped, the leaves are tufted, which is always the case when the rhizome is erect, as in *Athyrium Filix-fœmina*; and the arborescent kinds likewise exhibit the tufted growth of the leaves from a terminal bud, with little development of the internodes. The rhizomatous stems frequently branch, in which case the stem bifurcates, as in the Lycopodiaceæ.

The leaves of the Ferns resemble those of the Phanerogamia in their essential structure; they are very remarkable for their multifold compound forms. The venation or ribbing exhibits a peculiarity, the ramification of the veins in the laminæ being on a bifurcated plan (fig. 458, *b*, *d*), and the subdivisions retaining an equal size. The leaves are also characterized by the circinate vernation (§ 113) which is almost universal in the Order, the only exception being found in the *Ophioglosseæ*.

The fructification or sporiferous apparatus of the Ferns is produced upon the leaves; and it presents a great variety of modifications, which serve to characterize the principal subdivisions of the Order. The ***spores*** are formed in spore-cases or *sporanges*, little membranous sacs attached by a pedicle to the lower surface of the leaf (fig. 458, *b*, *c*, *i*, &c.), or to a kind of skeleton of the leaf in which the parenchyma is suppressed (*o*). These spore-cases differ in some essential particulars of structure, in the mode of attachment, and in their relations to each other.

Fig. 458.



Organization of Ferns:—*a*, plant of *Polypodium vulgare*; *b*, fragment of a pinna with naked *sori*; *c*, vertical section through one of the sori, showing the attachment of the sporanges to the leaf; *d*, portion of a pinnule of *Lastræa Filix-mas*, the sori covered with *indusia*; *e*, vertical section through a sorus of the same, showing the attachment of the indusium and sporanges; *f*, vertical section of a cup-shaped indusium and sorus of *Cyathea*; *g*, marginal sorus of *Hymenophyllum*; *h*, the same, with one valve removed, to show the attachment of the sporanges; *i*, sporange of *Polypodium*, bursting; *k*, sporange of *Hymenophyllum*; *l*, sporange of *Schizæa*; *m*, group of sporanges of *Mertensia*; *n*, sporange of *Osmunda*; *o*, portion of the fertile lobe of the frond of *Botrychium Lunaria*, with the sporanges burst; *p*, spores of Ferns.

In most of the Filices the spore-cases possess an *annulus* or ring (fig. 458, *i*), an incomplete ring of thickened cells running round the sac, and assisting, by its contraction when dry, to rupture the sac and set free the spores. In the *Polypodieæ* and other tribes it is vertical (fig. 458, *i*); in the *Hymenophylleæ* the ring is oblique and unconnected with the basal pedicle (*k*); in the *Gleicheniœ* the ring is horizontal (*m*); and in the *Schizæeæ* it forms a kind of cap with radiating striæ on the top of the spore-case (*l*); in *Osmundeæ* the ring is broad, but imperfectly developed (*n*), while in Marattieæ and Ophioglosseæ (*o*) it is absent altogether.

In most of the tribes the spore-cases are distinct from one another, but collected in groups (*sori*) of various forms, round, linear, &c. (fig. 458, *b*, *c*), on the lower surface of ordinary leaves, or of leaves especially devoted to the fructification and modified in form and texture. The *sori* are either *naked* (*b*, *c*), or covered by a membranous cover or *indusium* (*d*, *e*), the forms and modes of attachment of which furnish systematic characters. In the Marattieæ the spore-cases are usually more or less coherent together, so as to form a false compound multilocular sporange. In the *Hymenophylleæ* the sporanges are attached to little columns formed by the production of the ribs beyond the margins of the leaves (*g*, *h*), becoming at the same time enclosed in cup-like receptacles formed from the margins of the leaf. In the Ophioglosseæ a portion of the leaf is transformed into a simple or compound spike-like process, covered with free spore-cases destitute of a ring, and splitting regularly to discharge the spores (*o*).

The *spores* are simple cells of microscopic dimensions, furnished, like pollen-grains, with a double coat, the outer of which is generally similarly marked with papillæ, reticulations (*p*), &c.

The term "flowering" fern is erroneously applied to those kinds in which the fertile leaves or lobes are destitute of parenchyma, and thus resemble superficially the spadices of Phanerogamia, as *Osmunda*, *Botrychium*, *Ophioglossum*, &c.

The arborescent Ferns belong to the Polypodieæ and Cyatheeæ, and differ only in habit and dimensions from the more familiar forms.

Ferns are sometimes reproduced by buds, analogous to bulbils, formed on different parts of their structure, and sometimes at the points of the leaves.

Various attempts have been made to explain the morphology of the sporanges, or *thecæ*, and the *indusium*. We believe the latter must be regarded as a product of the lower epidermal layer of the leaf; and the sporanges are doubtless, like the anthers on the surface of the male scales of *Cycas*, developments of the parenchymatous structure, which scarcely admit of comparison with the proper appendicular organs of stems. Some authors, however, describe the leaves or "fronds" of Ferns as branches; and then the *sori* admit of being regarded as developed from leaf-buds, the leaves of which become sporanges (clustered together like the spines in the abortive buds of Cactaceæ).

**Affinities, &c.**—The Filices constitute a very large and natural group of Cryptogamous plants which have no very close relations, as regards general structure; but the Ophioglosseæ seem to form a link between *Osmundeæ* and Lycopodiaceæ. As regards the physiological processes occurring in reproduction, this Order must be classed with the Equisetaceæ, notwithstanding the great diversity of habit, which, as a whole, may be expressed by saying that the leaf predominates in the Ferns and the stem in the Horse-tails.

The *Ophioglosseæ* depart importantly from the general characters, both in their foliage and their reproductive organs; to the form of the latter there is an approach in Marattieæ, and perhaps we may admit that the sporanges of this Order are really like those of Lycopodiaceæ: the development of the young spores appears to agree, however, with that of the Ferns and Equisetaceæ, which is on a totally different plan from that of Lycopodieæ. Ophioglossaceæ are sparingly represented in Europe and North America, the West Indies, at the Cape, Tasmania, &c., but are most abundant in the Indian islands. They seem to be without active properties.

The *Marattieæ*, by the absence of the annulus and the grouping of the sporanges, appear to stand between the Polypodieæ and the Ophioglosseæ.

The Ferns of temperate climates in the northern hemisphere are herbs; in the islands of the tropics and the south temperate latitudes arborescent forms occur having the habit of Palms. The Ferns are universally distributed—more abundantly, however, in damp, mild climates, which favour the development of foliage. Some of them have active properties, astringency, anthelmintic and emetic qualities, &c., but they are of little importance; the rhizomes of *Pteris* &c., and the stocks of some arborescent kinds, afford a poor nutriment, used by the aborigines of the South-Sea Islands and elsewhere in times of scarcity. It need scarcely be mentioned that this is the favourite Order of Cryptogamia among cultivators of plants.

## CLASS III. AXOGAMIA.

536. Angiosporous Flowerless plants, producing antheridia and archegonia in the axils of their leaves or in proper buds, the fertilized archegonia giving birth to sporanges filled with numerous spores, all reproducing the plant.

This title is applied to the Mosses and Liverworts on account of the development of the *archegonia* and *antheridia* upon the perfect leafy plants, the fertilization of the archegonia being followed here by the development of the fruit containing the spores. Both groups exhibit a peculiar mode of germination, the spore being developed into a branched confervoid filament, upon which leaf-buds appear, growing up into leafy stems, bearing antheridia and archegonia and subsequently capsular sporanges; so that the perfect plant of a Moss corresponds to the heart-shaped *Marchantia*-like expansion of the prothallus of Ferns on which the antheridia and pistillidia are produced.

### ORDER CLXVIII. BRYACEÆ. MOSSES.

*Class.* Musci, *Endl.* *All.* Muscales, *Lindl.*

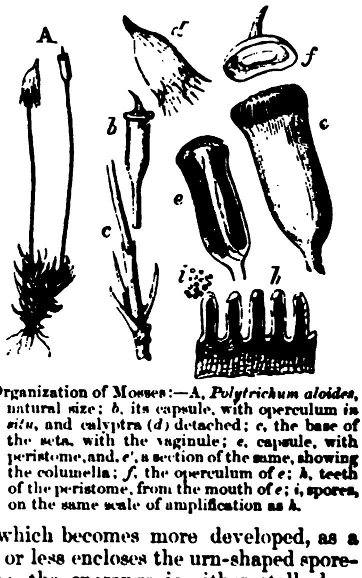
537. *Diagnosis.*—(Fig. 459.) Mosses, of cæspitose or diffused creeping habit, terrestrial or aquatic, with usually spirally imbricated leaves, and urn-shaped sporanges, terminal (*acrocarpous*), or on the ends of short lateral branches (*cladocarpous*), or from the axils of leaves (*pleurocarpous*), usually raised on a *seta* (fig. 459, A), covered at first by a *calyptra* (*d*), ultimately naked, then bursting (rarely)

irregularly, or by the separation of a lid (*operculum*, *f*), leaving the free margin of the capsule naked (*gymnostomous*) or fringed by a single or double row of teeth (*peristome, e, h*), whose number is a power of four, and which are free or combined by lateral processes; sporanges with a central *columella* (*e'*) and no elaters.

ILLUSTRATIVE GENERA.

Phascum, *L.*
Grimmia, *Ehrh.*
Tetraphis, *Hedw.*
Splachnum, *L.*
Dicranum, *Hedw.*
Trichostomum, *Hedw.*
Encalypta, *Hedw.*
Bryum, *L.*
Bartramia, *Hedw.*
Funaria, *Hedw.*
Polytrichum, *L.*
Hypnum, *L.*
Fontinalis, *L.*

Fig. 450.



Organization of Mosses:—A, *Polytrichum aloides*, natural size; *b*, its capsule, with operculum *in situ*, and calyptra (*d*) detached; *c*, the base of the seta, with the vaginule; *e*, capsule, with peristome, and, *e'*, a section of the same, showing the columella; *f*, the operculum of *e*; *h*, teeth of the peristome, from the mouth of *e*; *i*, spores, on the same scale of amplification as *h*.

The Mosses have thread-like or wire-like stems, which are either simple or branched; the former are erect, and terminate in fruits; the latter generally creep, and produce sporanges from the lateral shoots. The leaves are small and scale-like though green; mostly spirally arranged, but in one tribe, the *Hypopterygieæ*, they somewhat resemble those of Jungermanniaceæ. The leaves concerned in the formation of the fruit-buds (*perichætial leaves*) are often modified in form, and correspond to the bracts. The *antheridia* and *archegonia* are produced either in terminal buds or in the axils of stem-leaves, together or separately, and often in distinct plants. From the archegonium, the outer part of which is a flask-shaped membranous sac, arises the *sporange* or *theca*, which in its growth tears away the wall of the archegonium, leaving the base as a kind of collar (*vaginule*, fig. 450, *c*), and carrying away the upper part, which becomes more developed, as a cap or hood (*calyptra, d*): this more or less encloses the urn-shaped spore-case until it is mature (fig. 450, A); the sporange is either stalked or sessile; its stalk is called the *seta*. When the calyptra falls off, it exposes the *sporange* or *capsule* (*b*), which in most cases has a deciduous lid (*operculum*, *f*): when the lid falls off, the border of the mouth of the capsule is found either naked or furnished with a single or double fringe of teeth (*peristome*, *e, h*); and a circular piece, called the *annulus*, sometimes separates from the end of the *columella* in this situation. The number of teeth in the peristome is either four or some multiple of that number, as eight, sixteen, &c. A striking peculiarity of the capsule of the Mosses is the existence of the columella, or stalk-like process running up the centre of the cavity of the sporange (*c'*). In what are called Astomous Mosses there is no deciduous operculum, and in *Phascum* the capsule bursts irregularly; the columella is sometimes absorbed here, while the spores are ripening; in *Andræa* the sporange opens by four lateral slits, the valves remaining attached at the top. The spores of the Mosses are simple double-coated cells, like pollen-grains; they occur alone, and never accompanied by filamentous bodies.

The Mosses often produce gemmæ or reproductive leaf-buds analogous to the bulbils of Phanerogamia; they occur both on the stems and on the leaves. They form frequently also small confervoid filaments at the base of the stem from which gonidia-like bodies separate; and, according to Dr. Braxton Hicks, zoospores like those of Algæ are formed from the chlorophyll-utricles of these filaments.

**Affinities, &c.**—The characters of the antheridia and archegonia, the sexual reproductive organs of Mosses which give rise to the fruit, are noticed above; their mode of occurrence enters into modern descriptions of genera and species. The Bryaceæ, as limited in the above diagnosis, are closely related to Andræaceæ and Sphagnaceæ, commonly included among true Mosses; the former Order connects them with Hepaticæ, but the affinities of *Sphagnum* beyond Bryaceæ are obscure. The Mosses have no distinct affinities with any Cryptogamous Class except the Hepaticæ. The Bryaceæ are numerous, and present a great variety of structure very interesting to microscopists; they are generally diffused, most common in temperate climates; and their chief importance, perhaps, arises from their keeping, with the Lichens, the outposts of vegetation, at the Poles, on mountains, or on barren rocks.

## ORDER CLXIX. SPHAGNACEÆ. BOG-MOSSES.

*Class.* Musci, *Endl.* *All.* Muscales, *Lindl.*

538. *Diagnosis.*—Aquatic or bog-Mosses, of peculiar yellowish-green aspect, with spirally imbricated (5-rowed) leaves and fasciculate branches, the lower of which are long and deflexed, while one of the upper is, in fruiting plants, replaced by a sporange, with a short turbinate seta, dehiscing by an operculum, destitute of a peristome, and possessing a short columella and no elaters among the spores.

### ILLUSTRATIVE GENUS.

Sphagnum, *Dillen.*

**Affinities, &c.**—This genus differs very much from the Bryaceæ in habit and in the structure of its leaves, which are well-known as curious microscopic objects, the chlorophyll-bearing cells being slender and elongated, connected in a kind of network in the interstices between large empty cells, whose walls are strengthened by a spiral fibre; this structure causes the whitish or yellowish-green colour peculiar to them and a few other similarly organized Mosses. In addition to the fasciculate mode of branching (really formed by successive members of a spiral series), the *Sphagna* have antheridia like those of *Jungermannia*, globose stalked bodies, and not sessile tubulur sacs. There appears, moreover, to be some peculiarity in their spores, since they have been observed to occur in some cases of more than the ordinary size, and fewer of them in a capsule. This Order is not a little remarkable for the share which it takes in covering bogs and gradually furnishing material for peat, the lower parts of the stems continually dying away below while the summit ascends; the descending lower branches of the fascicles, which appear to supply the place of roots here, bind the whole into a compact mass. They abound in cold and temperate climates in boggy places, furnishing an article of food to animals, and even to man in northern regions.

## ORDER CLXX. ANDRÆACEÆ. SPLIT-MOSSES.

*Class.* Musci, *Endl.* *All.* Muscales, *Lindl.*

539. *Diagnosis.*—Cæspitose Mosses, with erect stems, imbricated leaves, and terminal fruit, the capsules destitute of a seta (sessile on the receptacle where the vaginule arises), bursting vertically into four valves which remain connected at the apex, possessing a central columella and spores not mixed with elaters.

ILLUSTRATIVE GENERA.

| | |
|---|---|
| Andræa, *Ehr.* | Acrochisma, *Hook. fil.* |

**Affinities, &c.**—*Acrochisma*, a genus from the Antarctic regions, has the valves separated only halfway down, thus connecting this Order with the *Phasceæ* among the Bryaceæ, in which *Archidium*, like *Andræa*, does not elevate the sporange on a seta, but carries up the calyptra simply by expansion of the capsule: on the other hand, the 4-valved dehiscence agrees with that of the Jungermanniaceæ, where, however, with other less important peculiarities, we have no columella, but elaters mixed with their spores. The species are native of mountains and polar latitudes.

## ORDER CLXXI. JUNGERMANNIACEÆ. SCALE-MOSSES.

*Class.* Hepaticæ, *Endl.* *All.* Muscales, *Lindl.*

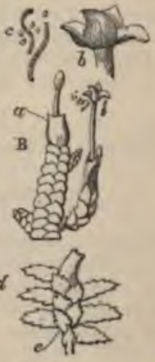
540. *Diagnosis.*—Minute creeping plants with small green cellular (scale-like) leaves, imbricately arranged along the axis in two rows, often with a row of imperfect leaves (*amphigastria*, fig. 460, *d*) on the underside: or with the stem thalloid, *i. e.* forming a lobed leaf-like mass. The sporanges are oval capsules breaking through the summit of the calyptra, raised on a thread-like seta, and splitting vertically when ripe into 4 valves, which separate more or less widely into the form of a cross (fig. 460, B), scattering spores mixed with elaters, destitute of a columella.

ILLUSTRATIVE GENERA.

Metzgeria, *Radd.*
Blasia, *Mich.*
Frullania, *Nees.*
Trichocolea, *Nees.*
Geocalyx, *Nees.*
Jungermannia, *Dill.*

The Jungermanniaceæ (or foliaceous Hepaticæ as they have been termed) have slender ramified creeping stems like those of branched Mosses, being more delicate, with leaves imbricated in a distichous manner, so as to give a flattened character to the branches (fig. 460, B, *d*). The *antheridia* and *archegonia* are produced on these stems; and from the latter are developed the *sporanges*, which are surrounded at the base by modified *perichætial* and *perigonial* leaves, and by a *vaginule* (fig. 460, B, *a*), which differs from that of the Mosses in being the entire sac of the archegonium, no hooded calyptra being carried up in the Jungermanniaceæ. The *vaginule* is sometimes called *calyptra*, and sometimes *epigone*; the circle of leaves, often confluent, surrounding it, form the *perigone*, *perianth*, or *involucel*; and these are surrounded by the *perichætial leaves*, *perichætium*, or *involucre*. The capsules are generally elevated on thread-like stalks (*setæ*), and when mature split nearly or quite to the base into four teeth (fig. 460, *b*), which spread out more or less and set free the *spores* and *elaters* (*c*). There is no columella.

Fig. 460.



Organization of Jungermanniaceæ:—B. *Radula complanata* with an unopened and a burst capsule: *a*, the vaginule; *b*, the burst capsule, magnified; *c*, spores and elaters; *d*, fragment of the leafy stem of *Jungermannia umbrosa*, showing the distichous arrangement of the leaves, and the *amphigastria* (*e*).

**Affinities, &c.**—The genera of this Order, formed out of the old genus *Jungermannia*, present a considerable variety of conditions, both as regards their vegetative structure, which is either frondose or foliaceous, and the minute details of the organization of the *calyptra* (*epigone*), with the *involucel* (*perianth* or *perigone*) and the *involucre* (*perichætium*) which surround it. They approach the Mosses through Andræaceæ; with which *Anthoceros* is still more nearly allied in the possession of a columella; but we have here a higher condition of the vegetative organs, nearer that of Mosses. The Jungermanniaceæ are found in shady woods, and moist situations, throughout all regions of the globe, most abundant in damp tropical woods. They have no important qualities.

(ANTHOCEROTEÆ are distinguished from the frondose forms of Jungermanniaceæ by the absence of an involucel (*perigone*). The *antheridia* and *archegonia* are produced in cavities excavated in the thalloid stem; and from the archegonium springs a thread-like or pod-like *capsule*, which splits down longitudinally into two valves when ripe, and displays a central *columella*, and has both *spores* and imperfect *elaters*.)

## ORDER CLXXII. MARCHANTIACEÆ. LIVERWORTS.

*Class.* Hepaticæ, *Endl.* *All.* Muscales, *Lindl.*

541. *Diagnosis.*—(Fig. 461.) Minute green plants, with a stem in the form of a lobed, leaf-like, cellular expansion, rooting by capillary filaments below, with an indistinct midrib; the sporanges depending from the underside of a capitate or radiate receptacle supported on a stalk arising from the apex, on the under surface, of the lobes of the frond; the sporanges bursting by teeth or irregular fissures, containing elaters mixed with the spores, but no columella.

### ILLUSTRATIVE GENERA.

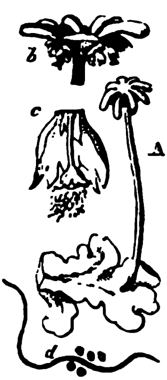
| Fegatella, *Radd.* | Plagiochasma, *Lehm.* | Marchantia, *March.* |
|---|---|---|

The Thalloid Hepaticæ have a broad, more or less succulent, lobed, leaf-like expansion in place of stem and leaf (fig. 461); this is to be regarded as a foliaceously developed stem analogous to that of *Lemna* among the Phanerogamia. The fruits borne by the thalloid forms are very varied: the *Pellieæ*, or frondose Jungermanniaceæ, bear capsules like those just described, but arising from the midribs of the thalloid stem; the Anthoceroteæ, Riccieæ, and Marchantiaceæ are very different.

The thalloid expansion of the Marchantiaceæ sends up stalk-like processes from its marginal sinuses (fig. 461, A), terminating in simple or divided cap-shaped bodies (*receptacles*), on the underside of which are found the *archegonia*; the *antheridia* are in distinct heads; the archegonia develope into *sporanges* or *capsules* (*b*), which usually burst at the apex (*c*) into four teeth, sometimes into eight; in certain genera a lid separates by transverse dehiscence, and in others the sporange bursts irregularly; the sporange has *no columella*, and its *spores* are mixed with *elaters* (*d*).

The Hepaticæ produce cellular bulbils or gemmæ. These are especially remarkable in some of the thalloid forms, as in *Marchantia*, where they are developed in groups in special cup-like receptacles.

Fig. 461.



**Organization of Marchantiaceæ:**—A. *Marchantia polymorpha*, bearing a receptacle of fruit; *b*, vertical section of the receptacle, showing the sporanges on its under surface; *c*, sporange bursting, with its vaginule and perigone laid open; *d*, spores and elater highly magnified.

**Affinities, &c.**—This Order is especially characterized by the existence of a stalked "receptacle" bearing the reproductive organs, which, unlike the stalked sporanges of the allied Orders, is not a product of the archegonia, but preexists and bears these, distinct receptacles being produced for the antheridia. The sporanges, with the calyptra, involucel, &c., are formed in groups from a number of archegonia, developed on the receptacles; this structure distinguishes Marchantiaceæ at once from Jungermanniaceæ, and from the frondose Ricciaceæ, which have the sporanges immersed in the frond and devoid of involucres. The Marchantiaceæ grow in damp shady situations, occurring in all climates.

(RICCIACEÆ are inconspicuous *Marchantia*-like Liverworts, growing in mud or floating on water, having a delicate cellular leaf-like "frond," with the sporanges, without an involucel or involucre, immersed in or sessile on the frond, bursting irregularly, and containing no elaters. The antheridia and archegonia are also imbedded in the substance of the thalloid stem. From Anthoceroteæ they differ in the absence of a columella and of rudimentary elaters. They are interesting as exhibiting the lowest type of organization in the Class to which they belong. They are generally diffused, comprising 8 genera, with about 28 species. Genera: *Riccia*, Mich.; *Duriæa*, B. and Mont.; *Sphærocarpus*, Mich.)

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## ORDER CLXXIII. CHARACEÆ.

*Class.* Algæ, *Endl.* *All.* Algales, *Lindl.*

542. *Diagnosis.*—Water-plants having verticillately branched stems, rooting more or less at the joints; the stems either simple tubes, or with the central tube clothed by a cortical stratum of smaller tubes which grow over the internodes from the top and bottom and meet so as to envelope it. Reproductive organs of two kinds, found on the whorls of branches:—(1) axillary oval sporangia (*nucules*), consisting chiefly of a central cell with a cortex of spirally wound tubes ending in a crown of teeth above; and (2) little globular antheridia (*globules*), sessile on the branches, bursting when mature into 8 triangular valves, the centre of each valve bearing a stalk whence arise microscopic, jointed, confervoid filaments, each joint of which gives birth to a 2-ciliated filamentous spermatozoid. The nucules fall off, germinate, and produce new plants.

### ILLUSTRATIVE GENERA.

| Chara, *L.* | Nitella, *Ag.* |
|---|---|

**Affinities, &c.**—The true relations of this very interesting group of plants form a subject of debate among botanists: as regards the organization of the stems, they do not rise above the condition met with in *Polysiphonia*, or even *Batrachospermum*, among undoubted Algæ. On the other hand, their vegetative structure has the power of reproducing the plants by bulbils developed on a far higher type than the ordinary cellular gemmæ of the lower plants; further, the presence of distinctly formed roots growing from the nodes seems to show that they are really Cormophytes, in which, possibly, the leaves are represented by the cortical filaments of *Chara*. From the organization of the reproductive organs taken alone, little hesitation can be felt in associating the Characeæ with the Vascular Cryptogams, the spermatozoids of which are exactly represented in the products of the globules, while this form of the fertilizing structure does not exist in the Thallophytes; and the "nucule" must be regarded as a representative of the archegonium of the Mosses &c. (see PHYSIOLOGY). The *Charæ* grow in stagnant water, fresh or salt; and many of them acquire a dull aspect and brittle texture by becoming incrusted with carbonate of lime, apparently precipitated from calcareous matter in the water, since it is often deficient in cultivated specimens. The unincrusted kinds, the simple tubes of *Nitella*, and the young shoots generally are well known as objects displaying in a beautiful manner the rotation of the cell-sap, which takes place in every part of these plants. The abundant protoplasmic cell-contents cause these plants to give off a very offensive odour when decaying. The species occur all over the world, most commonly in temperate climates. They have no known uses, and are regarded as noxious from their smell when undergoing decomposition.

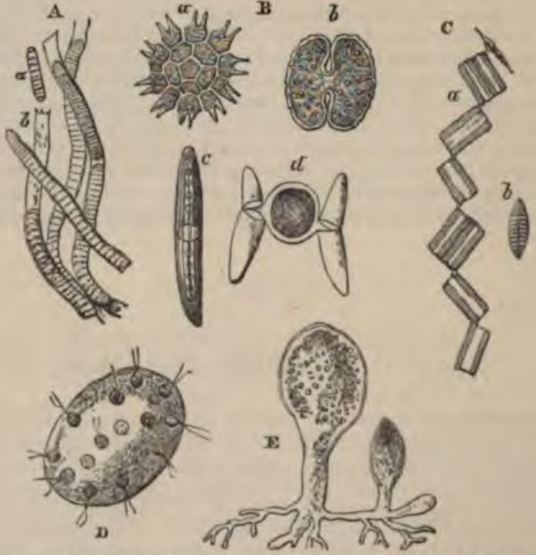
## DIVISION II. Gymnosporæ (Thallophyta).

543. Cryptogamous plants producing in vegetation a thallus, presenting no opposition of ascending and descending axis, or contrast of stem and leaf; antherozoids never spiral; reproduced by spores which are produced in parent cells, either forming part of the vegetating thallus or growing upon the surface of definite regions of the thallus devoted to reproduction. Spores not producing a prothallus, but reproducing the plant immediately.

These plants correspond to the Thallogens of most authors; their principal points of distinction from Angiosporous Cryptogams are above given. The vegetative structures of the plants of this group, which form their principal bond of connexion one with another, and their most striking character of distinction from the higher plants, present a great variety of conditions within their own limits. The *thallus* is a purely cellular expansion, presenting no contrast of parts analogous to that between the axis (stem) and the appendages (leaves and their modifications), which exists in the higher plants; hence they are necessarily devoid of true buds. A special regularity, however, and a determinate direction of growth are manifested more or less clearly in all cases, giving definite and characteristic forms to the *thallus*. This is the case even when the thallus is reduced to the condition of microscopic filaments, which elongate and spread in determinate directions.

The *thallus* is exclusively composed of cellular tissue; and its more minute differences in the various classes and families of this division of the Vegetable Kingdom require microscopic investigation; but certain broad distinctions may be laid down, sufficient for the general discrimination of the classes in the more perfect forms. The lower forms of the three classes of Thallophyta approach very closely in their characters, on account of their great simplicity of organization, which excludes the possibility of many differential characters.

Fig. 462.



Algæ.—A. *Oscillatoria autumnalis*: *a*, filament escaped from the sheath, *b* (magn. 300 diameters). B. *Desmidieæ*: *a*, *Pediastrum Boryanum*; *b*, *Cosmarium margaritiferum* (200 diam.); *c*, *Closterium Lunula* (30 diam.); *d*, *Closterium acerosum* in conjugation, with the resulting spore (200 diam.). C. *Diatomaceæ*: *a*, *Diatoma vulgare*; *b*, end view of a cell (200 diam.). D. *Volvocineæ*: *Pandorina Morum* (100 diam.). E. *Botrydium granulatum* (15 diam.).

## Class I. HYDROPHYTA or ALGÆ.

544. Gymnosporous Cryptogams living in water or in damp places exposed to the light, extremely variable in size, form, colour, and texture, free or attached by root-like organs, sometimes unicellular, at other times having a branched pseudo-stem and leaf-like appendages, sometimes of large size, but exclusively cellular in structure and destitute of stomata. Plants multiplied by subdivision of cells or by the formation of "zoospores." Reproduction or formation of spores effected by the antherozoids emitted from the antheridia and sporanges, either on the same plant (monœcious) or on different ones (diœcious). Spores motionless, solitary, or in groups of four in a single sporange.

The most familiar examples of this Class are the Seaweeds; but it also includes a great number of plants found in fresh water and in damp situations, many of which are altogether of microscopic dimensions, and invisible, except in quantity, to the naked eye.

The lowest forms, the *Palmelleæ*, consist of simple cells, of most varied shapes, usually found connected together in definite or indefinite masses by gelatinous excretion or products of the decomposition of the older cells (fig. 465, B, *a*). The individual cells, each often representing a distinct plant, are characterized by a wonderful diversity and, in certain families, beauty of form, as in the *Desmidieæ* and *Diatomaceæ* (fig. 462, B, C); sometimes, as in the Volvocineæ, they are provided with vibratile cilia, and exhibit an active spontaneous motion (fig. 462, D). As a rule their colour is green, an important exception to this being formed by the *Diatomaceæ*, which have another special peculiarity in the existence of a siliceous deposit in their walls, which remains as an indestructible skeleton after the decay of the organic matter of the plants. Some of these lower Algæ are found of red colour; but in many cases, at least, this colour is only characteristic of certain stages of growth of kinds which are green when vegetating actively. It is very probable that most of these so-called unicellular or pseudo-unicellular Algæ are really not independent organisms, but stages of growth of some other plant, perhaps of much higher structure. Thus there is reason to think that these unicellular bodies may not only be stages in the development of Lichens, but even of Mosses (see p. 422). One remarkable point in their history is the length of time they will persist unchanged; but under altered circumstances it would appear as if they were developed into Lichens or Mosses.

A step forward in complexity of organization is made in the filamentous Algæ, composed of cylindrical cells attached end to end, and thus forming long jointed tubes, either simple or more or less branched (fig. 465, A, C); the Confervoideæ and their allies, the "silk-weeds" of freshwater pools, afford familiar examples of this structure; these grow at the extremity of the filaments, or interstitially by all the joints elongating simultaneously.

The *Ulveæ* have a thallus where growth in breadth is added to that in length; some of them also acquire a certain thickness; in this way they become leaf-like expansions, of membranous texture. They grow by additions all round the margin of the anterior part, often lobed or divided, but of homogeneous tissue throughout: the form and dimensions of the thallus become more or less definite here; the colour is mostly green, as in the *Confervoideæ*.

The Red Seaweeds or Rhodospermeæ exhibit almost every possible form between that of the branched filamentous thallus and that of a highly compound or dissected leaf (fig. 463, A), or a shrub-like collection of firm branches; and moreover the texture of the thallus varies from a simply membranous to a cartilaginous or even horny substance, caused by greater development of the cellular tissue, which in the higher kinds exhibits a distinction between the cortical or epidermal layer and the internal spongy parenchyma. The Corallines, which belong to this group, acquire a stony character from the deposition of carbonate of lime in their cellular tissue. The colours vary in this Order; they are red, purple, brown, olive, &c., but never pure green, like the Confervoids.

The Olive-coloured Seaweeds, including the Fucaceæ (of which the "Bladder-wrack" is the commonest example), and others of very different organization, the Phæosporeæ and Dictyotaceæ, exhibit a similar gradation of form in the thallus. The lower forms of Phæosporeæ present tufts of branched filaments; the higher forms of these, and the Fucaceæ, have thick leaf-like or stem-like fronds of firm texture and sometimes enormous dimensions; many of them have a shrubby habit of growth, and attach themselves to stones &c. by discoid or branched expansions from the base, resembling superficially the roots of the higher plants, but having no similar function or anatomical character. The thallus of the larger forms is highly developed as to its tissues, having a distinct cortical layer; but the structure is strictly cellular, without a trace of woody fibre or vascular elements. The colour is here usually olive, brown, or some dull tint of green-brown; never bright green, as in the Confervoids.

The reproduction of the Algæ takes place in an almost infinite diversity of modes, which can only be treated of very generally here, as many of them involve the necessity of a thorough knowledge of the elementary structure of plants. These matters will be again referred to in the Physiological part of this work.

Vegetative reproduction assumes a very important place in the multiplication of all Thallophyta. Throughout the Algæ it is a constant phenomenon, and one illustrating very beautifully the physiological homogeneity of the thallus.

The lowest forms multiply by dividing into a number of cells or grains which grow up to the dimensions of the parent; this occurs as the ordinary mode of growth, here confounded with reproduction, in the *Palmelleæ* (fig. 465, B, *a*, *b*), *Desmidieæ*, *Diatomaceæ* (fig. 462), &c.

In some of the unicellular Algæ, as also in the Confervoideæ, a process called "conjugation" occurs, which is by some considered a sexual process, while others look on it as a mere form of bud-growth. Two cells come into proximity, a communication is established from one to the other, the contents of the one mingle with those of the other, and form a spore (fig. 462, B, *d*).

But another still more remarkable form of vegetative reproduction extends from these up to the highest Algæ, namely the reproduction by *zoospores*. This consists in the conversion of the semifluid contents of individual cells (the endochrome) into distinct corpuscles, and the expulsion of these from the thallus by the bursting of the parent cell-membrane (fig. 465, C, *d*); these corpuscles are filled with green or olive-coloured matter, except at one end, which is provided with cilia and is sometimes spoken of as the "rostrum." The cilia are excessively minute, and vary in number in different genera; sometimes the whole surface of the zoospore is covered by them. These zoospores are usually emitted at a fixed hour in the morning, as the result of an endosmotic action which causes the cell-wall to burst and set free the zoospores; sometimes before their liberation they are seen to congregate in one portion of the cell, and, as it were, to strike against the cell-wall and cause its rupture. Their activity seems to be directly dependent on the influence of light. After moving spontaneously for some time, the zoospores lose their cilia, become encysted, and grow up into new thalli. In some Algæ, moreover, there are two sorts of zoospores—large ones, called *macrogonidia*, and smaller ones, called *microgonidia*. Pringsheim even describes a form of zoospore which has the faculty of remaining dormant for long periods, and even of resisting desiccation for several months, at the expiration of which time, if circumstances be favourable, it germinates and forms a new plant. To such zoospores the name of *chronizoospore* has been given. The formation of zoospores may take place in any or all of the cells of the thallus of the filamentous and foliaceous confervoid; it occurs in certain definite parts of the thallus of the Phæosporeæ, where there is a difference in the constituent tissues. It has not been observed in the Red Seaweeds or the Dictyotaceæ—where, however, a distinct kind of organ is found, called a *tetraspore* (fig. 463, B, *c*), which appears to be the representative of gemmiparous reproduction,—nor in Fucaceæ, where the only known kind of reproduction is by sexual organs.

Sexual reproduction has been made out clearly in Algæ belonging to the Confervoid and Fucaceous groups, and recently in the Rhodospermeæ. The Phæosporeæ at present are only known to produce *zoospores*. The essential phenomenon throughout is the emission from an *antheridium* of antherozoids which are endowed with a power of locomotion, and ultimately come into contact with a cell, which, in consequence, develops into a spore, which may be one of the ordinary cells of the thallus set apart for this purpose, or may be contained in a special fruit.

In the Confervoideæ, where the spores are developed from ordinary cells, there are no special reproductive organs; the spores formed in the impregnated cells acquire thick coats (fig. 465, A, *c*, *d*), usually assume a red or brown colour, and are set free by the decay of the parent cell.

In the Fucaceæ the fructification is limited to definite parts of the thallus. In *Fucus* or *Halidrys* (fig. 464), which may be taken as examples, the reproductive structures are formed at the ends of the lobes of the thallus. Externally the lobe (called the *receptacle*) presents a thickened appearance, marked with numerous distinct orifices (fig. 464, *a*); these orifices lead to chambers imbedded in the thickness of the thallus (called *conceptacles*, *b*), bearing on their walls cellular sacs of two kinds—one, the larger (*spore-sacs*, *e*), containing the spore-germs, the smaller (*antheridia*, *c*) containing *spermatozoids* (*d*) or impregnating corpuscles; both kinds of sac burst and discharge their contents when ripe, and the spores are fertilized and encysted while swimming freely in the water.

The Rhodospermeæ and Dictyotaceæ, besides *tetraspores*, have *spore-sacs* and *antheridia*, mostly collected in "fruits" of definite form, sometimes in patches or lines (*sori*) on the surface of the thallus, like the sori of Ferns, sometimes imbedded in definite groups in its substance (called *favellæ*), sometimes projecting more or less from the surface or margins of the thallus (fig. 463, D, *d*, E), when they are naked or surrounded by a gelatinous or cup-like involucre (*favellidia*, *coccidia*, *ceramidia*). The *antheridia* are usually found arranged in groups in similar situations (fig. 463, F, *a*); and the *tetraspores* are either scattered or collected in fruits analogous to those containing the spores and antheridia (fig. 463, B, *c*). The antherozoids are immobile, and fertilize the sporange by means of a special tube projecting from the latter and called the *trichogyne*. Transformed branches containing imbedded tetraspores are called *stichidia*. The sexual organs are often found on distinct plants, which are thus diœcious.

Further details respecting the reproduction are reserved for the Physiological portion of this work. The definite characters of the Orders of Algæ are subjoined.

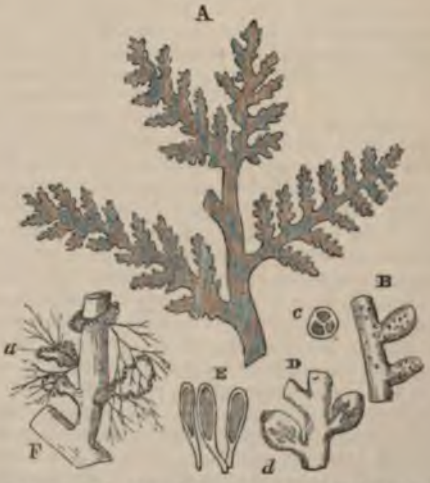
545. Harvey divided the Algæ into 3 groups, which he named, respectively, Chlorospermeæ or green-spored Algæ, Melanospermeæ or olive-spored Algæ, and Rhodospermeæ or red-spored seaweeds, the subdivisions being thus founded mainly on the colour of the spores. Decaisne's classification nearly coincides with that of Harvey, so far as the limitation of the group is concerned; but it is formed on a more philosophical basis. As modified by Thuret, it stands thus:—Zoosporeæ, with moveable spores; Aplosporeæ, with green or brown motionless spores; Choristosporeæ, with red motionless spores developed in fours.

## ORDER CLXXIV. RHODOSPERMEÆ OR FLORIDEÆ.
### RED SEAWEEDS.

*Class.* Algæ, *Endl.* *All.* Algales, *Lindl.*

546. *Diagnosis.*—(Fig. 463.) Marine Algæ, mostly of red, purple, rarely olive or brownish colour, with a thallus either foliaceous or of branched filaments, sometimes incrusted with carbonate of lime. Reproduced by *spores* (E) formed in special sporangia, which are

Fig. 463.



Organization of Rhodospermeæ:—A. Part of a thallus or frond of *Laurencia pinnatifida* B. A magnified fragment of a lobule with stichidia containing tetraspores like *c*, a more magnified figure. D. Lobule of the frond bearing ceramidia or spore-conceptacles: *d*, the spores. E. Spores from the same, more magnified. F. Lobule of a frond bearing antheridia, *a*.

either superficial or plunged in the frond, and contained within special cavities or "conceptacles" (D) of varied form. The sporange is provided with a special tube, or "*trichogyne*," by means of which it is fertilized by the antherozoid; accompanied by *antheridia* (F), containing a single motionless antherozoid without cilia, and by *tetraspores* (B, C), collections of 4 cells formed in special parent cells in similar situations to those of the spores.

### ILLUSTRATIVE GENERA.

Subord. 1. RHODOMELEÆ.
  Rhodomela, *Agh.*
  Polysiphonia, *Grev.*
Subord. 2. LAURENCIEÆ.
  Laurencia, *Lamx.*
  Chylocladia, *Grev.*
Subord. 3. CORALLINEÆ.
  Corallina, *Tournef.*
  Melobesia, *Lamx.*
Subord. 4. DELESSERIEÆ.
  Delesseria, *Lamx.*
  Plocamium, *Grev.*
Subord. 5. SPHÆROCOCCEÆ.
  Plocaria, *Nees.*
  Sphærococcus, *Grev.*
Subord. 6. CRYPTONEMIEÆ.
  Phyllophora, *Grev.*
  Chondrus, *Grev.*
Subord. 7. CERAMIEÆ.
  Callithamnion, *Lyngb.*
  Griffithsia, *Agh.*
  Ceramium, *Adans.*
Subord. 8. PORPHYREÆ.
  Porphyra, *Agh.*

**Affinities.**—In spite of the varieties of form presented in this Order, there is so close an essential agreement in their organization that they distinctly appear as members of one natural group, with characters whose value is only equivalent to that of some of the subdivisions of the groups Fucoideæ and Confervoideæ of Harvey and others, with which they are usually placed parallel. The character of the spores seems to be the same throughout, although the fruits in which they are contained offer several successive degrees of complexity: the *favellæ* of *Ceramieæ*, and the *favellidia* of *Cryptonemieæ*, immersed or superficial groups of spores surrounded by a hyaline coat—the *coccidia* of *Delesserieæ*, hollow cases with thick membranous walls, containing a dense tuft of spores arising from a central peduncle—and the *ceramidia* of *Polysiphonia* &c., ovate or urn-shaped cases with thin and membranous walls, having a tuft of spores at the base—all these are but slight modifications of one (the conceptacular) kind of fruit, which produces the true spores. The various modes of arrangement of the *tetraspores*, which appear from Pringsheim's observations to be *gonidia*, or gemmulary bodies, since they grow up at once into a new thallus, while the other spores do not, the scattered arrangement, the *sori* or definite groups, and the *stichidia* or metamorphosed branches enclosing tetraspores, have a like relation; and an analogous relation runs through the modes of arrangement of the *antheridia*, which, it may be mentioned, are rarely found in the same individuals of the species as the spores. The antheridia discharge minute spherical corpuscles, to which the best observers deny the power of active motion, as is the case in regard to the *spermatia* of Lichens and Fungi; but they are generally supposed to have a fertilizing function (see PHYSIOLOGY). The simpler forms of thallus occurring in this Order relate it to *Ulveæ* and *Confervoideæ,* while the existence of tetraspores, globular spores, and antheridia in the Dictyotaceæ makes that Order form a direct transition to the Fucaceæ. The mode of fertilization, by means of the antherozoids, and the trichogyne, is described under the head of Reproduction.

**Distribution.**—The Red Seaweeds are generally diffused, but diminish from warm temperate latitudes both to the equator and the poles. They occur in deeper water than the Olive Seaweeds, and below tide-marks, flourishing best in quiet bays.

**Qualities and Uses.**—The abundant gelatinous or horny substance of the thallus of many kinds, composed of a modification of cellulose related to gum and starch, renders them nutritious: *Chondrus crispus* is the "Carrageen" or Irish Moss; *Rhodymenia palmata*, *Iridæa edulis*, and other plants of the Order yield a similar excellent jelly when boiled. *Plocaria tenax* is largely used by the Chinese for making glue. Some have pungent qualities, as *Laurencia pinnatifida*, called "Pepper-dulse." *Plocaria Helminthochorton*, Corsican Moss, has the reputation of being anthelmintic. The *Corallineæ*, including common Corallines (*Corallina officinalis*) and "Nullipores" (*Melobesia*), long supposed to be of animal nature, are very curious on account of their complete interpenetration by carbonate of lime, giving them a brittle and sometimes stony character.

(DICTYOTACEÆ are olive-coloured Seaweeds with a continuous thallus, bearing the reproductive organs in definite groups or lines (*sori*) upon the surface—the spores, tetraspores, and antheridia being all developed in an analogous manner from the cortical layer, bursting through its cuticular pellicle. This small Order is included by Decaisne in the Section Laminarieæ of the Tribe Aplosporeæ, but has been shown by Thurèt to be quite distinct from the other Olive-coloured Seaweeds; it is very interesting as presenting, in a special condition, exactly similar spores, tetraspores, and antheridia to those of the Rhodospermeæ, which they thus connect with the Fucaceæ, with which they agree in habit and were formerly combined. They belong rather to warmer localities, and are more delicate than the Fucaceæ, sometimes, as in *Padina*, exhibiting attractive colours. They are of no known use. Genera: *Dictyota*, Lamx.; *Dictyopteris*, Lamx.; Taonia, *J. Agh.*; Padina, *Adans.*)

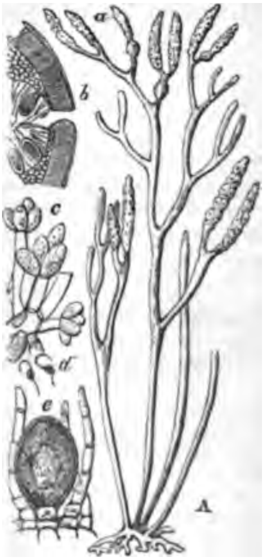
## ORDER CLXXV. FUCACEÆ. SEA-WRACKS.

*Class.* Algæ, *Endl.* *All.* Algales, *Lindl.*

547. *Diagnosis.*—(Fig. 464.) Olive-coloured Seaweeds of gelatinous, cartilaginous, or horny texture, with a foliaceous or shrub-like or cord-like thallus, attaching itself to rocks by a simple or lobed and ramified discoid base; fructification in *receptacles* formed out of lobes of the fronds (*a*), the external surface of which is pierced with orifices leading to chambers (*conceptacles*, *b*) lined with filaments intermixed with *spore-sacs* (*e*) or filamentous *antheridia* (*c*), or both of these; the olive-coloured spores 4 or 8 in a spore-sac, from which they escape when mature, and are fertilized by the active 2-ciliated

corpuscular spermatozoids (*d*) after they are detached from the parent.

Fig. 464.



Organization of Fucaceæ:—A. *Halidrys siliquosa*, half the nat. size: *a*, pods or receptacles; *b*, section through receptacle, showing the mouth of a conceptacle, the cavity of which is lined by antheridia (*c*) producing spermatozoids (*d*), and by spore-sacs (*e*).

### ILLUSTRATIVE GENERA.

Sargassum, *Rumph.*
Cystoseira, *Agh.*
Halidrys, *Lyngb.*
Himanthalia, *Lyngb.*
Pycnophycus, *Kütz.*
Fucus, *L.*

**Affinities.**—Some of the filaments lining the conceptacles become, after a time, swollen, and are filled by brownish matter; this brown matter is developed into 2, 4, or 8 spores, which escape from a small orifice at the apex of the conceptacle, through which also subsequently pass the tufts of sterile hairs which do not undergo metamorphosis into spores. Sometimes the antheridia are present in the same conceptacles as the sporanges; or they are borne on a separate plant (diœcious). The antheridia consist of ovoid cells, some on branched threads and containing a whitish mass, interspersed throughout which are a number of red granules. The antheridia are ejected through the orifice of the conceptacle, and themselves give exit to numerous antherozoids, each provided with a couple of extremely fine cilia, and containing a red granule. According to our present knowledge the Fucaceæ are strikingly separated from the other Olive Seaweeds—from the Dictyotaceæ by the absence of tetraspores and by the character of their antheridia, and from the Phæosporeæ by the absence of the reproductive zoospores and by other points of organization. They appear to be allied to the Confervoid forms, through Phæosporeæ, more closely than to Rhodospermeæ; but their reproductive organs are formed on a higher type.

**Distribution.**—Universal: especially found on rocks between tide-marks, or, if growing in deeper water, buoyed up to the surface by vesicular floats; very large in the Southern Ocean.

**Qualities and Uses.**—The gelatinous substance of which the thallus is composed renders some of these plants available as food for man or animals where better productions are scarce; but their chief value is as a source of iodine, extracted from the "kelp" or ashes, which were formerly an important source of soda also. The *Fuci* are also largely used for manure in maritime localities. *Sargassum bacciferum* forms the celebrated masses of "Gulf-weed" in the Atlantic Ocean. *Fucus vesiculosus*, the common Bladder-wrack, grows everywhere on our coast between tide-marks.

## Order CLXXVI. PHÆOSPOREÆ. Olive Seaweeds.

*Class.* Algæ, *Endl.* *All.* Algales, *Lindl.*

548. *Diagnosis.*—Olive-coloured or brown Seaweeds with a foliaceous, shrubby, or branched filamentous thallus; reproduced by *zoospores*, having two cilia, one directed forwards, the other backwards, formed in clavate cells or multicellular filaments, collected in more or less definite groups on the cortical layer of the thallus of the larger kinds, in lateral tufts or terminal on the branched filamentous kinds.

Illustrative Genera.

Chorda, *Stackh.*
Laminaria, *Lamx.*
Dictyosiphon, *Grev.*
Punctaria, *Grev.*
Desmarestia, *Lamx.*
Myriotrichia, *Harv.*
Ectocarpus, *Lyngb.*
Myrionema, *Grev.*
Leathesia, *Gray.*

**Affinities.**—This group corresponds to the tribe Laminarieæ of the group Aplosporeæ of Decaisne. The genera included in this Order with highly developed thallus approximate to the Fucaceæ, with which they are sometimes associated; but it has been discovered by Thuret that the so-called "spores" are sacs producing zoospores, which germinate and produce new plants like those of Confervoids; they are distinguished, however, from the zoospores of that group by the arrangement of the cilia, which are here two in number, unequal in size, and take reverse directions as they leave the body of the zoospore, resembling, in fact, the form exhibited in the spermatozoids of *Fucus*. The size and number of the zoospores are not constantly the same in the same plant; and in different cases the organs producing the zoospores are large clavate sacs or chambered filaments, the number of zoospores in a cell being either definite or indefinitely great, on account of more advanced segmentation of the contents. The mode of reproduction and the forms of the thallus in such genera as *Ectocarpus* &c. bring this Order very near to the Confervoideæ. Much obscurity still prevails here, since antheridia coexist with reproduction by zoospores in *Cutleria*, and appear to exist in *Sphacelaria* and *Cladostephus*, which also reproduce by zoospores.

**Distribution, Qualities, &c.**—Much the same as in Fucaceæ. *Laminaria digitata* and *saccharina* are eaten (under the name of Tangle) on the coasts of the north of Europe, as also is *Alaria esculenta.*

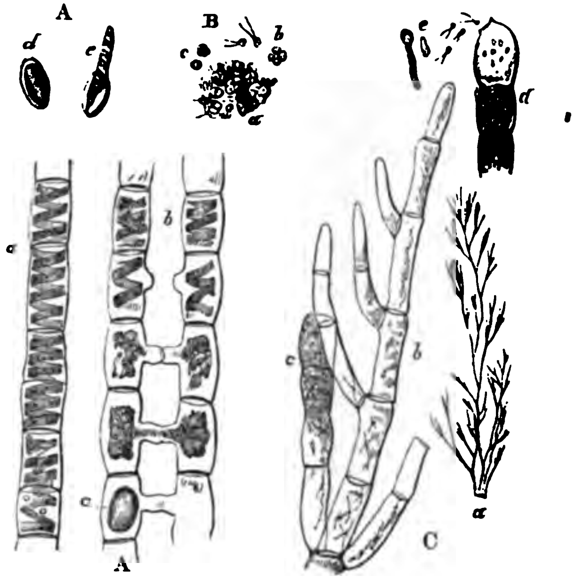
## Order CLXXVII. CONFERVOIDEÆ. Silk-weeds.

*Class.* Algæ, *Endl.* *All.* Algales, *Lindl.*

549. *Diagnosis.*—(Fig. 465.) Plants with a filamentous, membranous, gelatinous, or pulverulent thallus, growing in fresh or salt water, or on moist substances, of a bright green or, more rarely (often temporarily), red colour, reproduced by zoospores discharged

from the ordinary cells of the thallus (A, *d*), or by spores formed in these cells after impregnation by combination of the contents of two cells, either by conjugation (C, *c*), or by the transference of spermatozoids into the parent cell of the spore, the spores (C, *d*) passing through a stage of rest before germination.

Fig. 465.



Organization of Confervoid Algæ:—A. Filaments of *Spirogyra quinina*: *a*, in natural condition (magnified 50 diameters); *b*, two filaments conjugating; *c*, a spore formed in one cell from the mixed contents; *d*, a free spore; *e*, the same germinating. B. *Protococcus viridis* (magn. 200 diameters): *a*, a group of cells cohering by jelly-like matter; *b*, four cells formed by division of a cell of *a*, and two zoospores escaped from one of the cells, subsequently settling down as resting-cells, *c*. C. *Cladophora glomerata*: *a*, filaments, of natural size; *b*, the top of a branched filament, magnified; *c*, cells about to form zoospores; *d*, the same, with the zoospores escaping from the uppermost cell; *e*, zoospores germinating into new filaments.

### ILLUSTRATIVE GENERA.

Codium, *Stackh.*
Bryopsis, *Lamx.*
Vaucheria, *DC.*
Botrydium, *Wallr.*
Draparnaldia, *Bory.*
Œdogonium, *Link.*
Spirogyra, *Link.*
Sphæroplea, *Agh.*
Coleochæte, *Bréb.*
Hydrodictyon, *Roth.*
Ulva, *Agh.*
Tetraspora, *Dec.*
Nostoc, *Vauch.*
Botrydina, *Bréb.*
Clathrocystis, *Henf.*
Palmella, *Agh.*
(Achlya, *Nees.*)
(Chytridium, *Al. Br.*)

**Affinities.**—The specialities of the very multiform group represented by the above list of genera can scarcely be dealt with in a work like the present; and, in fact, our knowledge of the essential characters of the plants is at the present time undergoing a thorough reconstruction. In the definition of the group of Confervoids here, the Oscillatoriaceæ and the other *permanently* active forms are excluded. The Oscillatoriaceæ are organized in a very different way from the true Confervoids, while till lately it has been doubted whether *Diatomaceæ*, *Desmidieæ*, and, above all, Volvocineæ are even vegetables at all. The Confervoids proper are mostly very simple cellular organisms, with chlorophyll and starch in the cells while they are actively vegetating; the majority discharge the cell-contents in the shape of one or many active zoospores, with 2 or more cilia at a beak-like extremity, or with cilia all over the surface (*Vaucheria*); besides which process, sexual reproduction has been observed in *Zygnema* by *conjugation*, in *Œdogonium*, *Sphæroplea*, *Vaucheria*, *Bulbochæte*, &c. by spermatozoids derived from one cell entering the cavity of the parent cell of the spore; and in all probability this will be found general. The mode of fertilization will be found described under the head of Physiology of Reproduction. The spores formed after fertilization become encysted in a firm coat, thrown off in germination, which commonly ensues only after a long interval. The *Palmelleæ* are forms not yet well explained, composed of solitary cells imbedded in a common mucus; they appear to stand at the lowest point of organization in the Vegetable Kingdom, if they be not, like the "Yeast Plant" and similar conditions of Fungi, stages of growth of higher forms.

The genera above grouped by Professor Henfrey under the head of Confervoideæ are more naturally grouped by Decaisne under several distinct sections of varying degrees of importance as follows:—

1. *Confervæ*, comprising plants consisting of tubes or cells containing ovoid spores provided with 2–4 vibratile cilia.

2. *Unicellulares*. Plants consisting of a single cell producing numerous ciliated spores.

3. *Œdogonieæ*. Filamentous Algæ, producing spores either by the aggregation of the green colouring-matter of the cell into a spheroidal mass, which escapes from the parent cell by a special aperture in its wall, and is then seen to be provided with a crown of vibratile cilia, or as the result of sexual agency. The antheridia consist of filaments, each cell of which contains 1 or 2 spermatozoids, which escape by the lifting of a lid-like valve of the cell-wall and fertilize the spore as above stated.

4. *Vaucherieæ*. Unicellular Algæ, producing two kinds of reproductive organs—the one resulting from the concentration of the green matter at the extremity of the filaments into an oval active spore covered with cilia, the other formed as a result of sexual agency. The antheridia appear in the form of small horns placed in the proximity of ovoid sporangia. These antheridia contain numerous extremely minute spermatozoids, which escaping fertilize the sporangium and determine the formation of a spore, which does not germinate immediately, but only after the lapse of some time.

5. *Saprolegnieæ*. A group of imperfectly known Algæ, resembling the Vaucherias in their structure, presenting rounded, moveable, ciliated zoospores and also antheridial filaments, fertilizing certain spherical sporangia.

These plants are, by De Bary, regarded as belonging to Fungi, having similar powers of decomposing carbonic acid, and of living on organic matter, such as the bodies of flies or even of fish. They will be further alluded to under the head of Fungi.

6. *Synsporeæ* or *Conjugatæ.* Filamentous or unicellular Algæ, reproduced by the process of conjugation. This group comprises the Desmidieæ, of which further notice will be found hereafter.

7. *Diatomaceæ.* These are also alluded to in the following pages.

**Distribution, Qualities, &c.**—Met with universally in fresh and brackish water, some genera also on sea-coasts, growing on rocks, large Algæ, &c. Some of them occasionally appear suddenly in vast quantity, colouring lakes green; or, as in the case of *Palmella nivalis*, giving rise to the phenomenon called "Red Snow." *Palmella cruenta* often forms large patches of substance like half-coagulated blood on damp stones and rocks. The green slimy matter of stagnant pools is mostly composed of interwoven masses of filamentous Confervoids, which present most beautiful and varied forms under the microscope. *Ulva* (marine) produces large membranous fronds, which are sometimes eaten under the name of Green Laver.

(OSCILLATORIACEÆ. Microscopic filamentous structures, usually collected into patches of definite or indefinite form, extending by peripheral growth, composed of continuous tubular sheaths enclosing a green or brown gelatinous matter marked by transverse striæ, where the substance is divided into series of longer or shorter pieces, often escaping from the tube, ultimately resolved in reproduction into discoid fragments, which, when free, become globular. The gelatinous "core," the vital part of the structure, is capable of a peculiar movement, which causes the free portions or extremities of the filaments to vibrate like a pendulum, or with a slightly vermiform *oscillation*, whence the name of the Order. Reproduction by spores unknown. Our knowledge of the essential characters of this Order is very imperfect; and the only mode of reproduction known is by simple division of the central substance of the filaments, the portions slitting out of the ends of the sheaths and secreting a new coat of their own. Their peculiar oscillating motion is one of the marvels of Vegetable Physiology; they appear to be totally destitute of cilia. Their movements, and the nature of their central substance (apparently devoid of starch, and coloured by different matters besides chlorophyll), seem to indicate a relation between Oscillatoriaceæ and *Diatomaceæ*, which would connect the latter with Confervoids. They occur in water, fresh and salt, and on damp earth, everywhere. Genera: *Oscillatoria*, Bosc; *Microcoleus*, Desmaz.; *Calothrix*, Agh.; *Rivularia*, Roth.)

## ORDER CLXXVIII. DIATOMACEÆ.

*Class.* Algæ, *Endl.* *All.* Algales, *Lindl.*

550. *Diagnosis.*—(Fig. 462, B, C, page 428.) Microscopic unicellular plants, occurring isolated or in groups of definite form, usually surrounded by a gelatinous investment, the cells exhibiting more

or less regular geometrical outlines, and enclosed by a membrane striated or granular, either simply tough and continuous, or impregnated with silex and separable into valves. Reproduction by spores formed after conjugation of the cells (*d*), by zoospores formed from the cell-contents, and by division.

### Illustrative Genera.

Subord. 1. Desmidieæ (fig. 462, B). *Cell-membrane without silica, containing chlorophyll and starch.*

- Closterium, *Nitzsch.*
- Cosmarium, *Menegh.*
- Euastrum, *Ehr.*
- Pediastrum, *Meyen.*
- Desmidium, *Agh.*

Subord. 2. Diatomeæ (fig. 462, C). *Cell-membrane impregnated with silex, valvular, containing a brown colouring-matter.*

- Eunotia, *Ehr.*
- Diatoma, *DC.*
- Navicula, *Bory.*
- Isthmia, *Agh.*
- Melosira, *Agh.*

**Affinities, &c.**—These organisms were formerly included among Infusorial Animalcules; but the vegetable character is very strongly marked in *Desmidieæ*; and the reproduction by conjugation, characteristic of certain tribes of Confervoids, occurs not only in *Desmidieæ*, but in *Diatomeæ*, which in respect to general organization cannot well be separated from the *Desmidieæ*, although the nature of the cell-contents has more of the character of what we are accustomed to regard as animal substance. The *Diatomeæ* are also remarkable for the way in which they divide by segmentation into a number of distinct frustules, each of which grows into a perfect plant.

**Distribution, &c.**—*Desmidieæ* occur in all quiet pools of pure water, at the bottom or adhering to other plants. *Diatomeæ* are universally diffused, not only in fresh water, but in the sea and on moist ground, in all of which situations their siliceous cell-walls cause their remains to accumulate, if left undisturbed, until they may form actual mineral strata.

(Volvocineæ are microscopic bodies swimming in fresh water by the aid of cilia arranged in pairs upon the surface of a common semigelatinous envelope, the pairs of cilia each belonging to a green corpuscle resembling the zoospore of a Confervoid, imbedded in the periphery of the common envelope. Reproduction by the development of each corpuscle into a new colony, the whole being set free by the solution of the parent envelope, or by conversion of the corpuscles into encysted resting-spores like those of Confervoids. These curious and beautiful objects, found in similar situations with the Confervoids, appear more closely related to that group of organic beings than to any form distinctly recognizable as members of the Animal Kingdom; the persistence of the power of motion throughout the period of vegetative life being the only animal (?) character. Genera: *Volvox*, Lam.; *Pandorina*, Ehrenb.; *Stephanosphæra*, Cohn; *Gonium*, Lam.)

## CLASS II. AËROPHYTA.

551. Thallophytes growing and fructifying in the air, reproduced by spores formed in *asci*, and by green *gonidia* formed in the medullary layer of the thallus.

## ORDER CLXXIX. LICHENACEÆ.

*Class.* Lichenes, *Endl.* *All.* Lichenales, *Lindl.*

552. *Diagnosis.*—Plants usually of dry, dead-looking aspect, consisting of a thallus of foliaceous or shrubby form, or of scaly, crustaceous, leprous, horny, papyraceous consistence, bearing local fructification either in cavities in the thallus and opening ultimately by a pore on the surface (*angiocarpous*, fig. 466), or expanded into shield-like, cup-shaped, or linear projecting processes (*gymnocarpous*, fig. 467). Reproduction (vegetative) by *gonidia*, green cells at first hidden in the interior of the thallus, and by spores, 4–8 or a greater number, produced in tubular spore-sacs (*asci*, fig. 466, B), formed in the excavated or expanded fruits; antheridia (?) in special excavations of the thallus (*spermogonia*), producing minute stick-shaped corpuscles (*spermatia*, fig. 466, C).

### ILLUSTRATIVE GENERA.

Opegrapha, *Pers.*
Umbilicaria, *Hoffm.*
Verrucaria, *Pers.*
Endocarpon, *Hedw.*
Sphærophoron, *Pers.*
Cladonia, *Hoffm.*
Lecidea, *Ach.*
Stereocaulon, *Schreb.*
Parmelia, *Fr.*
Sticta, *Schreb.*
Cetraria, *Ach.*
Roccella, *DC.*
Ramalina, *Ach.*
Evernia, *Ach.*
Collema, *Ach.*

The thallus of the Lichens mostly grows in exposed situations, as on rocks, walls, the bark of trees, &c., never immersed in water like that of the Algæ, but receiving its supply of moisture from the atmosphere. It varies from a pulverulent or papillose crust to a leathery or horny foliaceous expansion (fig. 467, A), or tufted shrubby mass. In the crust-like forms it adheres firmly to the supporting object; in the foliaceous and shrubby forms it is free, and spreads more or less widely from its point of attachment. In all but the simplest forms it exhibits certain differences in its internal and external tissues; the thallus has a firm cortical layer above and below, between which, more or less developed in different cases, is a central looser mass composed of interlacing colourless cellular filaments. Among the latter occur green cells, called *gonidia*, which are capable of reproducing the plants vegetatively when set free. The cells of the cortical layer do not contain chlorophyll, and are usually dry, horny, and of a dull grey or brown colour. Crystals of oxalate of lime are often intermixed with the filaments of the central layers.

The fruits of the Lichens occur as modifications of two principal types, the shields (*apothecia*, fig. 467) and the conceptacles (*perithecia*, fig. 466). The perithecia are chambers excavated in thickened parts of the thallus, or in special branch-like lobes (fig. 466, *a*), opening externally by a pore, and lined by tubular sacs, the parent cells of the spores or *thecæ* (B). These thecæ contain usually a row of spores (4 or 8, or sometimes a larger number), which escape by the thecæ bursting, and are discharged from the orifice of the conceptacle or *perithecium*. The spores are very variable in size, and consist of two layers, an *epispore* and an *endospore*; the former is tinged blue on the addition of iodine. When the spores germinate they produce a filamentous thallus. In addition to the above-named reproductive organs there are others called *pycnidia*, whose nature and office are at present not clearly ascertained. They are like the spermogonia in form, and contain minute bodies called *stylospores*.

Fig. 466.

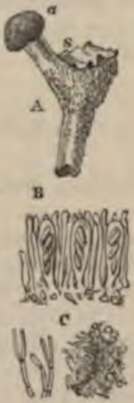


Fig. 467.

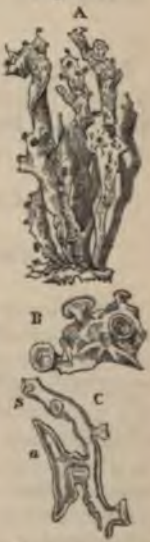


Fig. 466. A. Fertile branch of the thallus of *Sphærophoron coralloides*, with, *a*, a perithecium, and *s*, spermogonia. B. Thecæ and paraphyses from the perithecium. C. Spermatia from the spermogonium.

Fig. 467. A. Branch of *Ramalina fraxinea*. B. A fragment with apothecia. C. A section of a fragment magnified, showing, *a*, apothecium, and *s*, spermogonia.

The other form of fruit, the *apothecium* (fig. 467, C, *a*) consists of similar elements; but instead of being a closed chamber, it is a free open cup, or shield-shaped or linear body, sessile or stalked on the thallus, bearing the *thecæ* exposed on its upper face. Different names are applied by lichenologists to the various forms of the apothecium, according to the general form, such as *peltæ*, *scutellæ* (fig. 467), *patellæ*, *lirellæ*, &c.

Lichens with *perithecia* are called Angiocarpous, those with *apothecia* Gymnocarpous.

Smaller chambers, analogous in structure to the perithecia, but lined by filaments producing extremly minute bacilliform corpuscles, occur in the thallus of all Lichens (fig. 467, C, *s*); they are called *spermogonia*, and the corpuscles spermatia; they are supposed to represent *antheridia*, and the corpuscles to possess a fertilizing function.

The *spermatia* have usually been considered motionless or manifesting only the Brownian movement common to all minute particles, organic or inorganic; but Itzigsohn and other botanists affirm that they are endowed with a power of movement from place to place, as in the case of the antherozoids of other Cryptogams, and also with a movement on their own axis. Lortet affirms that the spermatia, unlike those of Mosses, are influenced by induction-currents of electricity; the spermatia range themselves in lines parallel to the direction of the current, as if polarized. When the current is broken, the spermatia disperse over the field of the microscope.

**Affinities.**—The relations of the Lichens to the Fungi are exceedingly close, so much so that it is difficult to discover an exact line of demarcation between the Angiocarpous Lichenes and the Pyrenomycetous Fungi. Some authors combine them into one class; but as a rule chlorophyll and starch do not present themselves in Fungi, while the gonidia of Lichens are coloured green by chlorophyll and they contain starch, and are hence coloured blue on the addition of iodine. Some botanists are of opinion that Lichens consist merely of the filaments of Fungi implanted on the tissue of an Alga. Others think that the 1-celled Algæ, whose development is like that of the gonidia of Lichens, are precisely those gonidia set at liberty. Famintzin says that "zoospores" are produced from the gonidia of Lichens. Some of the Lichens are truly parasitic; but the majority are only epiphytic, when they grow on bark &c. The thallus of Lichens has a great power of absorbing moisture from the atmosphere; hence the plants are enabled to grow on exposed rocks and in other dry situations.

**Distribution.**—All parts of the world, but forming a very large proportion of the entire vegetation in the higher regions of mountains and in polar latitudes.

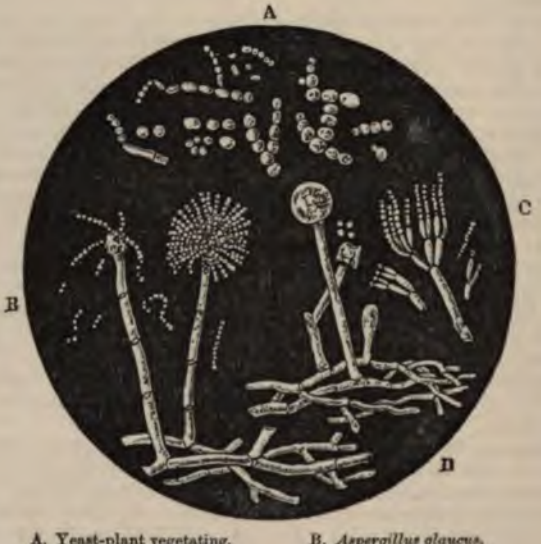
**Qualities and Uses.**—Many Lichens are very nutritious; a number of them yield valuable dyes; some are medicinal, others aromatic. Among the more important nutritious kinds are:—*Cladonia rangiferina*, "Reindeer Moss;" *Cetraria islandica*, Iceland Moss, and *C. nivalis*; *Umbilicaria* (various species), constituting "*Tripe-de-roche*" of the North-American hunters; *Lecanora esculenta* (Tartary) and *L. affinis*, *Sticta pulmonaria*, &c. From *Lecanora tartarea*, the purple dye called Cudbear is obtained; *Parmelia parietina*, common on walls and roofs, gives a yellow colour; *Roccella tinctoria* (Mediterranean and Cape-Verd Islands, &c.), *R. fuciformis* (Madeira, Angola, Madagascar, S. America), and *R. hypomecha* are Orchil-weeds, from which the dyeing material Orchil or Orchel is obtained—*litmus* being obtained from these and other species of *Roccella*. Some species contain a considerable quantity of oxalate of lime in the form of crystals.

## Class III. HYSTEROPHYTA or FUNGI.

553. Thallophytes growing in or on living or decaying organic substances, and fructifying in the air; vegetative organs or mycelium consisting of elongated cells, destitute of chlorophyll and starch; reproductive organs varied in form; spores external or formed in *asci*.

The Fungi exhibit the greatest simplicity and homogeneity in the vegetative structure, and a most wonderful and intricate complexity and variety in the organs connected with reproduction. The thallus is alike in construction in all Fungi, from the simple Mildew (fig. 468) up to the largest Agaric (fig. 469). It consists of an assemblage of branched, tubular, cellular filaments, containing no colouring-matter, and appearing in the form of simple filaments, or of fibres, or of membranes, or of gelatinous pulp, or of globular tubercles; the latter condition, indeed, is but transitory, and presents analogies with the formation of tubers from which shoots ultimately spring. In like manner the globular tubercles give origin to a filamentous mycelium. The clouds in decaying infusions, the "spawn" of Mushrooms, the woolly or cottony masses on the roofs and walls of cellars, the gelatinous mass of the "vinegar-plant," all present the same simple structure under the microscope, and all exhibit the same indefinitely expanding mode of growth from all free points; hence it results that they have no definite general form, and spread out more or less widely according to external conditions, dying away by degrees in the older central parts of the mass. This kind of thallus is known by the name of *mycelium*, and is of varying duration in different cases, sometimes annual, fructifying only once, or oftener in different species. It is apparently only capable of growth when it receives nourishment from organic substances, and is found therefore in rich vegetable mould, decaying organic matter, or parasitic on living plants or animals. It is almost always

Fig. 468.



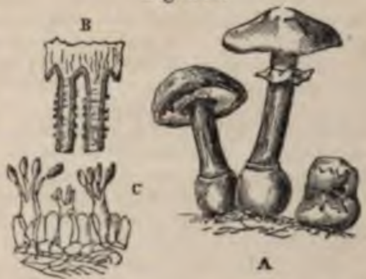
A. Yeast-plant vegetating. B. *Aspergillus glaucus.*
C. *Penicillium glaucum.* D. *Mucor Mucedo.*
Magnified 200 diameters.

colourless, sometimes brownish; but neither this nor any other part of the structure of Fungi contains chlorophyll or starch.

The reproductive organs of Fungi differ importantly in different Orders. The simplest plants of the Class are included in the Haplomycetous Fungi, including the Mildews and Moulds, which consist of a flocculent *mycelium*, from which arise free, simple or branched filaments of microscopic dimensions, terminating either in tufts of free spores, borne singly or in chains (fig. 468, B, C) at the ends of the branches of the filaments (Trichosporeæ and Arthrosporeæ), or in little sacs (fig. 468, D) filled with minute spores, which escape by the bursting of the theca (Cystosporeæ). The fructification of these plants appears to the naked eye, when in masses, like patches of delicate powder of various colours, grey, black, yellow, &c.

Many Fungi, growing in the substance of living or decaying leaves, bark, &c., form a fleshy or horny mass (*receptacle* or *stroma*) at some points on the surface of the mycelium; and in these are produced *conceptacular* chambers (*perithecia*), like those of the closed-fruited Lichens, the walls of which are clothed either with filaments bearing free jointed spores (*stylospores*), or with tubular sacs (*thecæ* or *asci*) containing spores in their interior, generally eight or some multiple of eight in number, and formed either by "free-cell formation," as will be explained hereafter, or by subdivision of the parent cell (Pyrenomycetous Fungi). Other Fungi, again, have similar asci or stylospores on the outside of a cup-shaped or cushion-shaped *special receptacle* (like an apothecium of a Lichen), scattered over a more or less distinct *stroma* or *common receptacle* (Discomycetous Fungi).

Fig. 469.



The Mushroom (*Agaricus campestris*):—A. Fruit, showing the expansion from the *volva*, and the veil tearing away and leaving the annulus. B. Section of "gills," magnified 50 diameters. C. Basidia and spores from ditto, magnified 400 diameters.

In the larger Fungi the fruit acquires more complex development. In the Agarics, the Mushroom is the large fleshy fruit arising from the flocculent mycelium, or "spawn" (fig. 469). The spores are produced here on little stalks (*sterigmata*) springing from the top of ovoid cells called *basidia*, which in their turn proceed from the *hymenium*, from which hang down the "gills" or vertical plates under the spreading cap (fig. 469, B). Many thousands of such spores are found on the gills of a single Mushroom. The gills are replaced by tubular or stalk-like processes, or convoluted laminæ, in allied genera. Fungi having this structure are called Basidiosporous, and are divided into two groups, Ectobasidieæ and Endobasidieæ, accordingly as the basidia are superficial, as in *Agaricus*, or enclosed within a conceptacle, as in the Puff-balls (*Lycoperdon*) and their allies. The fruit here assumes the shape of a leather ball, which at first appears solid, being filled internally by a convoluted laminar structure analogous to that under the pileus of the Agarics, but closely compacted and shut up in a sac (*peridium*) analogous to that enclosing the young Mushroom. The laminæ produce *basidiospores*; and these decay away so as to leave the spores free as a pulverulent mass in the interior of the ball, which then appears like a leathern sac, and, bursting, discharges the spores in the form of a cloud of dust—whence the name of the plants.

The family of which the Truffle is an example bear fruit beneath the surface of the soil in which they grow; and although they bear some resemblance to the Puff-balls, their structure differs in essential respects. They also are globular or irregular balls, the interior composed in like manner of convoluted laminæ, which gives a marbled appearance when they are cut across; but they do not produce *basidiospores*; from their sporigerous laminæ arise *asci* or spore-sacs, producing spores in their interior; and the ultimate fate of these is not to become free, dust-like particles, but to be set free by the rotting away of the whole parent mass. There is no *peridium* in this case.

The "spores" produced in the manner above indicated are probably more nearly analogous to buds than to reproductive organs formed from sexual agency. Accordingly as these spores are formed within a mother cell or on the exterior, we have the terms *endospores*, as in the *Ascomycetes* or *Pyrenomycetes*, or *exospores*, as in the Basidiosporeæ. Berkeley distinguishes the endospores as *sporidia*, retaining the word *spore* for the exospores. The endospores or sporidia are formed in one of two ways—either by division of the parent cell, or by the formation of new daughter cells within the mother cell (free-cell formation), as will be more fully explained hereafter.

Recent researches make it probable that various forms of so-called spores observed in Fungi have different physiological importance. Some of them, called *conidia* (fig. 468, A), appear to be organs of vegetative propagation, like the gonidia of Lichens (p. 441) and the zoospores of Algæ (§ 548). They exist in the form of simple, globular or ovoid cells, isolated or aggregated in masses. *Pycnidia* are small cavities or conceptacles containing threads, bearing ovoid or spheroidal cells called *stylospores*. In some Fungi, moreover, as *Peronospora*, *zoospores* like those of Algæ have been discovered, contained originally in a zoosporange, from which they escape and move from place to place by means of cilia.

Other of the structures met with among Fungi appear to represent distinct sexes; thus, in addition to the spores, usually so called, and the "sporidia," the following have also been observed in various Fungi:—*Antheridia*, or cystidia, of originally thread-like form, but afterwards dilated at the summit, and detached from the mycelium; the function of these bodies has not been definitely ascertained. *Spermatia*, consisting of simple, ovoid, straight, or curved cells, contained within a conceptacle or spermogone, and thus presumed to have close relationship to, if not identity with, the stylospores above described. *Zygospores*, rounded or oval cells, situated at the extremity of a filamentous receptacle or developed on the sides of two subdivisions of the same branch, which approximate and join one another to form a single cavity, or *zygosporange*, containing a single spore. This process, analogous to that called conjugation among Algæ, has only been observed in *Syzygites* and one or two other genera. Something of a similar character has been observed by Tulasne in *Peziza confluens*. *Oogonia* are globular bodies, filled with granular matter, which ultimately, after contact with the antheridium, formed on another branch of the same mycelium, aggregate into small globular masses, or *oospores*. These structures are found in *Saprolegnia*, a plant included by some under Algæ, but placed by De Bary in Fungi, and wherein small tubes like pollen-tubes may be seen passing from the antheridium into the interior of the oogone, and determining the formation of the oospore.

As many of the bodies which have thus received a distinct appellation are, in all probability, merely slight modifications of one and the same organ, it is very embarrassing for the student that they should have received different names. Doubtless, as the functions of these bodies become more clearly ascertained, Cryptogamic botanists will be content to follow the example of those who study the higher plants, and call all organs exercising the same functions by the same general name, qualifying it as may be necessary. The complexity is increased by the fact that one and the same species may develope at one time, or at different times, the various reproductive bodies above described. Hence numerous species and genera have been described as distinct, having been founded on the presence of organs now known to belong to the same plant in different phases of its existence.

Fungi live, for the most part, on dead or decomposing organic matter, or on living tissues. Hence M. de Bary divides Fungi into two Classes, the Saprophytes and the Parasites; and these latter are epiphytes or entophytes, accordingly as they attach themselves to the surface or develope themselves in the interior of the tissues. The spore of the parasite germinates externally, and thrusts the delicate filaments, formed as a result of its germination, through the epidermis, either through the stomata, or directly through the epidermis, as in the mould producing the Potato-disease. Each species of entophyte is peculiar to a particular plant, and penetrates it at a definite moment, and by an organ specially provided for the purpose. Thus De Bary asserts that the "white rust" so common in Crucifers is only introduced through the cotyledons at the time of germination. Epiphytical Fungi spread over the surface of the plant on which they grow, and abstract the juices therefrom by means of very small dilatations of the filaments acting as suckers. Other parasitical fungi affect animals, sometimes as a result or consequence of ill-health, while at other times the fungous growth itself causes the disease, as in the "fungous foot" of India, the silkworm-disease, &c.

554. The classification of the Fungi is a subject of great complexity, and, from the multitude of forms, and the variety of conditions exhibited under each type, it is extremely difficult to establish really natural groups with definite characters. Many systems exist, almost every writer who devotes especial attention to these plants modifying in some way the systems of his predecessors or contemporaries. It seems evident that we cannot rely on the condition of the spores alone for the discrimination of large groups, and it is scarcely possible to classify by the polymorphous fruits; but the conditions of the fruits seem to us the natural basis for the classification here, where the thallus takes the same simple form of a cottony mycelium

throughout the entire class. In De Bary's classification, which is the most recent, the Fungi are divided into four main subdivisions and thirteen secondary ones as follows:—1. *Phycomycetes*, including the *Saprolegnieæ*, *Peranosporeæ*, and *Mucorineæ*; 2. *Hypodermeæ*, including the *Uredineæ* and *Ustilagineæ*; 3. *Basidiomycetes*, comprising the *Tremellineæ*, *Hymenomycetes*, and *Gastromycetes*; 4. *Ascomycetes*, under which head are included the *Protomycetes*, *Tuberaceæ*, *Onygeneæ*, *Pyrenomycetes*, and *Discomycetes*.

In the former edition of this work Professor Henfrey proposed an arrangement of a simple nature, and which is as natural, or more so than other arrangement proposed before or since, for which reason it is retained. In it the Fungi were distributed into:—1. *Botrytaceæ*, the Order with fertile cellular filaments (*flocci*) arising directly from a flocculent mycelium (p. 445); 2. *Sphæriaceæ*, the Order with a *stroma* or *common receptacle* on the mycelium, bearing *perithecia* or *apothecia*, like the Lichens (p. 445); 3. *Exidiaceæ*, those with a highly developed *common receptacle* arising from the mycelium, and growing by peripherical development, bearing *basidiospores* or *ascospores* over more or less extensive tracts of the surface. In *Tubereæ* (Truffles) this receptacle is developed into a tubercular mass, formed of a convoluted structure with the sporiferous layer turned inside. 4. *Agaricaceæ*, in which a more or less complex *common receptacle* is originally developed in a large sac-like case or *peridium*, and either bursts out in a perfect form when ripe (*Agaricus* and *Phallus*), or decays and frees its spores within the *peridium* (*Lycoperdon* &c.).

## ORDER CLXXX. AGARICACEÆ.

(*Including most of the Hymenomycetes and Gasteromycetes of* Fries, *and the Basidiosporeæ of* Léveillé.)

555. *Diagnosis.*—(Fig. 469, p. 445.) Fungi vegetating by a flocculent thallus, from which arise more or less fleshy fruits which possess an outer, single, or double coat (*peridium*), rarely remaining adherent to the indehiscent fruit, usually bursting at maturity. *Peridium* enclosing the fructifying tissue (*gleba*), which forms a *common receptacle*, subdivided into numerous laminæ (fig. 469, B) or convolutions, or excavated into chambers, on the walls of all of which the spores are developed, either on *basidia* (C) or in *asci*. The *receptacle* either bursts forth out of the peridium when mature, and by expansion exposes its sporiferous laminæ, or it deliquesces and is totally absorbed before the bursting of the peridium, leaving this filled with free spores; or it gradually decays with the adherent indehiscent *peridium*.

### ILLUSTRATIVE GENERA.

Tribe 1. AGARICIEÆ.
Agaricus, *L.*
Boletus, *Dill.*

Tribe 2. PHALLEÆ.
Phallus, *L.*
Clathrus, *Mich.*

Tribe 3. PODAXINIEÆ.
Secotium, *Kze.*

Tribe 4. NIDULARIEÆ.
Cyathus, *Hall.*

Tribe 5. TRICHOGASTREÆ.
Lycoperdon, *Tournef.*
Bovista, *Dill.*

Tribe 6. MYXOGASTREÆ.
Trichia, *Hall.*
Stemonitis, *Gled.*

Tribe 7. HYMENANGIEÆ.
Hymenangium, *Klotsch.*

Tribe 9. ONYGENEÆ.
Onygena, *P.*

**Affinities.**—The question of the relations of the tribes of this Order and of this to the other Orders of Fungi cannot be deeply entered into here; but the principal forms may be briefly noticed in a general manner. These, like all other Fungi, grow from a flocculent *mycelium*, commonly known as "spawn." In *Agaricus*, the fruit appears at first as a roundish body, the *volva* or *peridium*, which bursts and gives exit to the "button," consisting of the stalk supporting the still closed pileus, its vertical sporiferous plates covered by the inner peridium, which splits away as the pileus expands, leaving a portion on the stalk in the form of the *annulus*. In *Boletus* the peridium is very fugacious. In *Phallus* the volva is more strikingly developed, and, when it bursts, the common receptacle expands into a column with the fertile surface at its head—in *Clathrus* into a wonderful coral-like network of fleshy substance with the spores adhering to the bars. *Podaxiniea* are a kind of Puff-ball in which there is a more or less distinct central column, comparable to the stalk of the pileus of an Agaric before this bursts out from its "button" condition. In *Nidularieæ* the peridium opens into a cup and exposes a number of little bodies formed by the breaking-up of the receptacular mass (*gleba*) into separate receptacles. *Trichogastreæ* are Puff-balls in which the entire sporiferous tissue in the peridium decays, leaving only the spores (or filamentous fragments), before the peridium bursts. *Myxogastreæ* are little plants which represent on a small scale the conditions of *Clathrus*, *Lycoperdon*, &c. *Hymenangieæ* approach the *Tubereæ* in the next Order; they are Truffles, or underground-fruiting Fungi, whose fruits may be compared to *Lycoperdon*, but remain solid and set free their spores by decay. *Tubereæ* differ from all the plants of this Order both by the absence of a *peridium* and by forming the spores in sacs or *asci*. All the *Agaricieæ* form their spores on *basidia*, grouped in fours.

**Distribution.**—Abundant in all parts of the globe upon or in soil containing decaying vegetable or animal matter, also upon decaying wood, trunks of trees, &c.

**Qualities and Uses.**—The fleshy fruits are formed of a tissue which is very nutritious; and in the absence of noxious secretions they are very excellent articles of food. In this country they are rather used as luxuries than necessities; but in Italy they are largely consumed as solid food; and in Australia, Tasmania, Tierra del Fuego, and other parts of the globe, where cultivation of the soil is not practised by the natives, they form an important item in the means of supporting life. The best-known wholesome kind is *Agaricus campestris*, the common Mushroom; but many other species of Agaric are also fit for food, as *A. deliciosus*, *A. procerus*, *A. Georgii*, &c., as also *Boletus edulis*; while a number of species of *Agaricus* (mostly such as are brightly coloured) are noxious or suspicious, as *A. piperatus*, *A. rachodes*, &c. The kinds of *Agaricus* and allied genera not eaten are commonly known by the general name of "Toadstools." Their peculiar mode of growth in pastures, producing, by their remains acting as a manure, annular marks of luxuriant growth of grass, called "Fairy-rings," results from the radiating growth of the subterranean mycelium or spawn. *Phallus* and *Clathrus* are genera of very curious structure, remarkable also for the excessively offensive smell diffused when the peridium bursts, and the receptacle expands. *Agaricus* (*Amanita*) *muscarius* is a poisonous species which possesses narcotic and intoxicating properties; the Puff-balls (*Lycoperdon* &c.) appear to possess a principle of this sort in a volatile condition, as the fumes from their combustion have a stupefying effect. *Lycoperdon giganteum*, however, when young, and snowy white in colour, is one of the best of the edible Fungi.

## ORDER CLXXXI. EXIDIACEÆ.

(*Including part of Hymenomycetes, of Discomycetes, and of Gymnomycetes,* Fries, *and of Basidiosporeæ and Thecasporeæ of* Léveillé.)

556. *Diagnosis.*—Fungi vegetating by a flocculent thallus, producing on any part of the surface more or less fleshy common *receptacles*, devoid of *peridium*, sometimes perennial and increasing continually in diameter, bearing on their surface crowded *basidiospores* or simple *stylospores*, or *asci* containing free spores ultimately discharged with elasticity.

ILLUSTRATIVE GENERA.

Tribe 1. POLYPOREÆ.
Merulius, *Hall.*
Polyporus, *Mich.*

Tribe 2. HYDNEÆ.
Hydnum, *L.*

Tribe 3. AURICULARIEÆ.
Cyphella, *Fr.*

Tribe 4. TUBEREÆ.
Tuber, *Mich.*

Tribe 5. HELVELLEÆ.
Helvella, *L.*
Morchella, *Dill.*

Tribe 6. TREMELLEÆ.
Tremella, *Dill.*
Exidia, *Fr.*

Tribe 7. CLAVARIEÆ.
Clavaria, *L.*

Tribe 8. ISARIEÆ.
Isaria, *Hill.*

**Affinities.**—The relations of this group are, in the first place, with the *Agariciea*, the *Polyporeæ* being as it were receptacles of *Agaricus* or *Boletus* without a peridium; they are remarkable for the fruit-organ being of perennial duration, increasing by gradual development at the margins. The *Hydneæ*, *Auricularieæ*, *Tremelleæ*, and *Clavarieæ* are all related in the same direction, the naked common receptacle exhibiting varying metamorphoses characterizing the particular groups. *Helvelleæ* are especially distinguished by the different mode in which the spores are developed, being ascosporous, in which they agree with *Tubereæ*, which may be regarded as *Polyporeæ* or *Tremelleæ* with the fertile layer of the receptacle turned-in to line a complicated series of connected chambers formed by convolutions of the mass. *Isarieæ* are probably rightly placed here, forming a link between this group and the filamentous Fungi.

**Distribution.**—Universal, on decaying vegetable matter, producing decay in damp situations.

**Qualities and Uses.**—Little value can be attributed to this Order on account of useful qualities; some of them, however, are eaten, especially the Truffles and Morels. *Morchella esculenta*, the Morel, is imported from Italy as an article of luxury. *Tuber* is the genus furnishing Truffles, which are highly esteemed for their peculiar penetrating flavour. *Tuber æstivum* is a British species, but it does not attain a large size with us. *T. melanosporum*, *magnatum*, *moschatum*, &c. are also used; most of those imported from France belong to the first of these species. The *Polyporeæ* have a great celebrity on account of the terribly destructive powers of the mycelium of various species, producing what is commonly called "dry-rot" in timber. The filamentous threads of the mycelium, corresponding to the cottony "spawn" of the Mushroom, insinuate themselves into the interstices of the fibres of wood, and exercising a solvent action on the substance, break down and assimilate the tissue until the solid mass is entirely destroyed. Like other Fungi, these grow most rapidly in damp and confined air; so that the "dry-rot" is really a *damp*-rot, resulting from the timber being too closely shut up from the atmosphere, which would keep it in a dry state and not allow the growth of the Fungus. We see an illustration of this in the decay of posts, beams, &c. where they enter damp earth, at joints where damp lodges, or when they are covered up, while green and wet, with paint or other impervious materials, while unpainted timber exposed freely to dry air does not suffer. The common dry-rot is produced by *Merulius vastator*, *M. lacrymans*, and *Polyporus destructor*; they frequently extend widely in the form of invisible mycelium without fruiting when they attack timber constructions; their fruits, often of very large size, are developed sometimes very rapidly, from parts of the mycelium which come to the surface of the wood; such fruits of *Polypori* and *Thelephoræ* are very common on rotten posts and trunks of trees. The fruit of *Polyporus squamosus* has been found more than 7 feet in circumference, and weighing 34 lbs., the whole the growth of a few weeks. The solid leathery substance of this fruit is cut into slices and dried and used for making razor-strops; that of *P. fomentarius* is made into "Amadou" or German tinder, by beating it into a kind of paste, soaking it in nitre, and drying it.

## ORDER CLXXXII. SPHÆRIACEÆ.

(*Including part of Discomycetes and Pyrenomycetes of* Fries, *and of the Thecasporeæ and Clinosporeæ of* Léveillé.)

557. *Diagnosis.*—Fungi vegetating by a flocculent mycelium (often parasitic on plants or even animals), producing a naked *common receptacle* of more or less horny texture, which bears, either in definitely formed groups on its outer surface (*receptacles*) or on the walls of chambers excavated beneath the surface and ultimately open externally (*conceptacles*), spore-sacs containing free spores (*asci*), or (by adherence of the spores to the wall of the parent cell) rows of separable *sporidia.*

### ILLUSTRATIVE GENERA.

Tribe 1. SPHÆRIEÆ.
- Sphæria, *L.*
- Hypoxylon, *Bull.*
- Cordiceps, *Tul.*

Tribe 2. PHACIDIEÆ.
- Tympanis, *Tod.*
- Cenangium, *Fr.*

Tribe 3. UREDINEÆ.
- Puccinia, *Pers.*
- Æcidium, *Gmel.*

Tribe 4. PERISPOREÆ.
- Erysiphe, *Hedw. fil.*

**Affinities.**—The relations of *Sphærieæ* and *Phacidieæ* with Lichens are so close that it is difficult to point out any good distinctive character, beyond the absence of chlorophyll in the thallus of this Order. They possess similar reproductive organs, the spores being formed in *receptacles* and *conceptacles* corresponding respectively to the *apothecia* and *perithecia* of Lichens, containing either spores in asci or stylospores (metamorphoses of the same structure) which both occur also in Lichens; and spermogonia with spermatia are formed exactly in the same way as in that Order. In *Sphærieæ* the receptacle is well developed, less so in *Phacidieæ* and merely forming a more or less distinct perithecium to the conceptacles in *Uredineæ* and *Perisporeæ.*

**Distribution.**—Universal; but mostly parasitic or upon dead organic structures.

**Qualities and Uses.**—The "uses" of these plants are not such as we are accustomed to comprehend under that name, since they refer to the general scheme of creation and not to human requirements; some of them are, indeed, among the pests of cultivation, in particular instances capable of doing enormous mischief. *Sphærieæ* attack living and dead organic bodies; *Cordiceps purpurea,* which attacks the young pistils of Rye and other Grasses, developes its mycelium within the ovary into a solid mass, which forms the "Ergot," so well known for its poisonous properties; the receptacle grows up subsequently from this, after it has fallen from the ear of the Rye. *Cordiceps Robertsii, entomorrhiza,* and other species attack the bodies of living caterpillars, and gradually destroy all the internal parts, and fill the skin with a solid mass of mycelium, which after a time sends up a filiform or clavate receptacle bearing the conceptacles, as in the Ergot Fungus. *Sphæria* includes numerous species, with less-developed receptacles, growing upon leaves, wood, bark, &c. of trees. *Hypoxyla* grow upon decaying wood, probably exerting a destructive action: when they are placed in situations unfavourable to the production of fruit, they often form large amorphous masses of hard fungoid substance, sometimes described as distinct kinds of Fungus under the name of *Sclerotium*, *Rhizomorpha*, &c. The *Phacidieæ* grow on vegetable bodies, chiefly those decaying after the completion of their vital function, as on fallen leaves, bark, &c. The *Uredineæ* attack the leaves and herbaceous organs of living plants, their mycellium ramifying in the tissues beneath the epidermis, and pushing out perithecia (or conceptacles) through the latter at various points; they constitute some of the most noxious vegetable pests of agriculture and horticulture, *Puccinia graminis* forming the "Mildew" of Wheat, the stylosporous forms of the genera of this same tribe (known as species of *Uredo*) constituting the "blights," "rusts," &c. of corn and other cultivated plants, *Coleosporium*, the "white rust" of Cabbages, &c. &c. Among the *Perisporeæ*, *Erysiphe* includes a number of epiphyllous Fungi, the mycelium of which spreads over the surface of living leaves, forming a cottony web obstructing growth and respiration, reproducing itself on an enormous scale by *conidia* or detached terminal cells of branches (*Oidium*), as well as by spores formed in conceptacles. The Vine-mildew has been referred to this tribe under the name of *Oidium Tuckeri*; it appears rarely to produce perfect fruit.

## ORDER CLXXXIII. BOTRYTACEÆ.

(*Including Haplomycetes of* Fries (= *Hyphomycetes and Physomycetes*), *Cystoporeæ*, *Trichosporeæ*, *and Arthrosporeæ of* Léveillé.)

558. *Diagnosis.*—(Fig. 468, p. 444.) Microscopic fungi vegetating by a flocculent thallus, often parasitic, of which the filaments rise up directly into simple or ramified pedicels, bearing at the extremity (or the ends of their branches) a free spore, a chain of spores (fig. 468, B, C), or an expanded cell filled with free spores discharged by dehiscence (fig. 468, D).

### ILLUSTRATIVE GENERA.

Tribe 1. ANTENNARIEÆ.
Antennaria, *Corda.*
Tribe 2. DEMATIEÆ.
Cladosporium, *Lk.*
Dematium, *P.*
Tribe 3. MUCEDINEÆ.
Penicillium, *Lk.*
Aspergillus, *Mich.*
Botrytis, *Mich.*
Tribe 4. MUCOREÆ.
Mucor, *Mich.*

**Affinities.**—The filamentous Fungi or "Moulds" are connected with the Orders with a naked receptacle by the relation of *Dematieæ* to *Isarieæ*, while the *Antennarieæ* are probably allied to the conceptacular Fungi through *Perisporeæ*. In *Antennarieæ* the flocculent mycelium is highly developed, and the spore-fruit is produced at once from it, the parent-cell of the spores being surrounded by a kind of false *perithecium* growing up over it in the form of cellular filaments. In *Dematieæ* the mycelium is little developed, and the pedicels bearing the spores are rigid and dark-coloured: they are not clearly understood at present. In *Mucedineæ* a flocculent mycelium sends up solitary simple or branched filaments with the free points tipped with a single spore or chains of spores falling off when ripe; the mycelium is also freely increased by *conidia*, consisting of globular or oval joints of the mycelium-filaments, falling apart instead of growing out into flocks. In *Mucor* the fertile pedicels are tipped with a globular cell enclosing a number of minute free spores. In *Syzygites* there has been observed a process of "conjugation" like that of some Algæ.

**Distribution.**—Universal, forming moulds, mildews, &c.; occurring constantly in infusions of organic matter and even chemical solutions, as "mother," producing various fermentations and decompositions.

**Qualities and Uses.**—Some of these insignificant plants are of vast utility to man through the chemical changes which they produce in the substances in which they flourish. In their perfect forms they present themselves as moulds, mildews, &c., as in:—*Mucor Mucedo*, the common mould of paste, &c.; *Penicillium glaucum*, the blue, green, or yellow mould which equally or still more readily appears on decaying vegetable substances; *Aspergillus glaucus*, the green mould of cheese; *Botrytis vulgaris*, a brown mould constantly attacking leaves decaying in a moist atmosphere &c. The Potato-fungus, *Botrytis infestans*, is another example. But some of these will grow extensively and increase by vegetative reproduction (by *conidia*, or isolated cells thrown off by budding of the mycelium) to an almost unlimited extent in suitable media: thus *Penicillium glaucum* grows in saccharine liquids, in the form of flocculent or gelatinous masses, constituting the curious object called the Vinegar-plant, the vegetation of which converts the solution of sugar into vinegar. This grows at ordinary temperatures. There is every reason to believe that the Yeast-plant, the growth of which produces the "fermentation" of beer and other liquids, and the "working" of bread, is a mycelial form of *Penicillium glaucum*, wholly composed of *conidial* cells which never grow out into filaments, but bud continually into new *conidia* under the influence of the elevated temperature which is requisite to produce this fermentation. Hallier considers it to be the conidial state of a *Leptothrix*.

(A detailed account of the most important phenomena exhibited in the development of Fungi, Lichens, and Algæ will be found in the "Micrographic Dictionary." In the systematic study of these Classes and of the Cryptogamia generally, the student must have recourse to Mr. Berkeley's 'Introduction to Cryptogamic Botany.')

# ARTIFICIAL ANALYSIS OF THE CLASSES AND PRINCIPAL ORDERS*.

## Series I. **PHANEROGAMIA—FLOWERING PLANTS.**

| | |
|---|---|
| Div. I. Flowers with pistils containing the ovules in closed ovaries ............ | ANGIOSPERMIA. |
| Div. II. Flowers imperfect and incomplete, consisting of scales, the female with naked ovules, on the margins or upper face of the scales, or isolated .............. | GYMNOSPERMIA. |

### Div. I. **Angiospermia.**

| | |
|---|---|
| *Class* 1. Cross section of the *stem* exhibiting one or more complete rings of wood dividing a central pith from a separable rind or bark; *leaves* mostly with arborescently branched reticulated ribs; *calyx* and *corolla* mostly 5- or 4-merous; *embryo* with two opposite cotyledons .................... | DICOTYLEDONES. |
| *Class* 2. Cross section of the *stem* exhibiting the wood in isolated fibres, without distinct pith or bark; *leaves* mostly with parallel ribs, or, if reticulated, with the secondary ribs suddenly smaller; *calyx* and *corolla* 3-merous (perianths apparently 6-merous); *embryo* with one cotyledon, or a rudiment of a second alternate .................... | MONOCOTYLEDONES. |

*Class*. 1. DICOTYLEDONES.

| | |
|---|---|
| *Subclass* 1. Petals distinct, free, emerging directly from the receptacle; stamens hypogynous ........................ | A. *Thalamifloræ* (197). |
| *Subclass* 2. Petals distinct or coherent, hypogynous or perigynous; stamens perigynous or epigynous .................. | B. *Calycifloræ* (250). |
| *Subclass* 3. Petals coherent, hypogynous or epigynous; stamens epipetalous, or more rarely hypogynous .................. | C. *Corollifloræ* (292). |
| *Subclass* 4. Petals absent, or forming a green perianth with the sepals; sepals green or coloured, sometimes abortive.......... | D. *Incompletæ* (336). |

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* The arrangement in the following Table is purposely made different in some particulars from that given in the detailed list of Orders, so as to increase the student's facilities for determining the Order to which any particular plant may belong. As it is drawn up for beginners, it refers almost exclusively to Orders or representatives of Orders commonly to be met with, either in a wild state or cultivated in gardens in this country.

### A. THALAMIFLORÆ.

- I. Placentas parietal.
  - *a.* Seeds exalbuminous.
    - * Flower regular.
      - 1. Stamens 6, tetradynamous …… *Cruciferæ*, 14.
      - 2. Stamens numerous …… *Capparidaceæ*, 15.
      - 3. Stamens equal to the petals, or double …… *Tamaricaceæ*, 22.
    - ** Flower irregular …… *Resedaceæ*, 16.
  - *b.* Seeds albuminous.
    - * Flower irregular.
      - 1. Stamens 5 …… *Violaceæ*, 20.
      - 2. Stamens 6, diadelphous …… *Fumariaceæ*, 13.
    - ** Flower regular.
      - 1. Sepals 2 …… *Papaveraceæ*, 12.
      - 2. Sepals 5, æstivation imbricated …… *Droseraceæ*, 19.
      - 3. Sepals 5, æstivation contorted …… *Cistaceæ*, 18.
- II. Placentas covering the dissepiments …… *Nymphæaceæ*, 9.
- III. Placentas axile, or on the ventral suture of simple pistils.
  - *a.* Seeds albuminous, with a straight embryo in the axis.
    - * Fruit composed of several separate carpels.
      - 1. Flowers perfect, pentamerous or tetramerous …… *Ranunculaceæ*, 1.
      - 2. Flowers perfect, trimerous; trees or shrubs.
        - Leaf-buds enclosed by stipules, æstivation imbricated …… *Magnoliaceæ*, 3.
        - Leaves exstipulate, æstivation valvate …… *Anonaceæ*, 4.
      - 3. Flowers, through abortion, diclinous …… *Menispermaceæ*, 5.
    - ** Fruit composed of 1 carpel; anthers dehiscing by valves …… *Berberidaceæ*, 8.
    - *** Fruit two- or many-celled, composed of coherent carpels.
      - 1. Flowers irregular, perfect …… *Polygalaceæ*, 35.
      - 2. Flowers regular, diclinous by abortion …… *Xanthoxylaceæ*, 47.
      - 3. Flowers regular, perfect.
        - Stamens opposite the petals …… *Vitaceæ*, 50.
        - Stamens alternate, monadelphous …… *Oxalidaceæ*, 41.
        - Stamens alternate, distinct …… *Rutaceæ*, 46.
        - Stamens numerous, free or polyadelphous …… *Tiliaceæ*, 27.

| | |
|---|---|
| *b.* Seeds albuminous, with the embryo curved round the albumen (in part apetalous) | *Caryophyllaceæ*, 23. |
| *c.* Seeds exalbuminous. | |
| * Flowers regular. | |
| 1. Fruit a many-celled capsule. | |
| Stamens definite, distinct | *Elatinaceæ*, 32. |
| Stamens definite, monadelphous at the base | *Linaceæ*, 40. |
| Stamens numerous, polyadelphous | *Hypericaceæ*, 31. |
| Stamens numerous, distinct or coherent at the base | *Camelliaceæ*, 29. |
| 2. Fruit of several carpels arranged round a columella. | |
| Stamens numerous, monadelphous, with 1-celled anthers | *Malvaceæ*, 24. |
| Stamens definite, monadelphous; anthers 2-celled | *Geraniaceæ*, 42. |
| 3. Fruit succulent (hesperidium) | *Aurantiaceæ*, 39. |
| 4. Fruit a 2-lobed samara | *Aceraceæ*, 34. |
| ** Flowers irregular. | |
| 1. Calyx not spurred, 5-merous; embryo curved | *Sapindaceæ*, 33. |
| 2. Calyx spurred. | |
| Embryo curved | *Balsaminaceæ*, 43. |
| Embryo straight | *Tropæolaceæ*, 44. |

As a rule the Thalamifloræ are polypetalous. Some Rutaceæ and Anonaceæ are monopetalous. Apetalous genera and species occur in Ranunculaceæ, Menispermaceæ, Papaveraceæ, Caryophyllaceæ, Byttneriaceæ, Tiliaceæ, Geraniaceæ, Rutaceæ, Xanthoxylaceæ, &c.

Some of the foregoing Thalamiflorous Orders include native species in which the petals are abortive, especially Ranunculaceæ and Caryophyllaceæ: this is more frequently the case with exotic species of these and other Orders of this Subclass.

## B. CALYCIFLORÆ.

| | |
|---|---|
| I. Polypetalæ. | |
| ¶ Placentas parietal. | |
| *a.* Seed exalbuminous. | |
| * Flowers perfect | *Cactaceæ*, 75. |
| ** Flowers diclinous | *Cucurbitaceæ*, 72. |
| *b.* Seeds albuminous. | |
| * Stamens epigynous. | |
| Stamens 5, distinct | *Ribesiaceæ*, 76. |
| Stamens 5, monadelphous | *Passifloraceæ*, 71. |
| Stamens numerous | *Mesembryanthaceæ*, 69. |

| | |
|---|---|
| ** Stamens perigynous. | |
| Leaves without stipules ........ | *Portulacaceæ*, 68.<br>(Some *Saxifragaceæ*, 65.) |
| Leaves with stipules............ | *Paronychiaceæ*, 67. |
| ¶¶ Placentas axile, or on the ventral suture of the separate carpels. | |
| *a.* Seeds exalbuminous. | |
| * Leaves with stipules. | |
| 1. Fruit free, a legume or lomentum ...................... | *Leguminosæ*, 55. |
| 2. Fruit free, a drupe ............ | (*Amygdaleæ*), 56. |
| 3. Fruit a succulent or dry etærio, or a succulent or dry cynarrhodum ...................... | *Rosaceæ*, 56. |
| 4. Fruit a pome, with a core or 2–5 stones, and a superior calyx .. | (*Pomeæ*), 56. |
| ** Leaves exstipulate. | |
| 1. Fruit with the calyx adherent. | |
| Stamens and petals numerous | *Calycanthaceæ*, p. 263. |
| Stamens numerous, petals 5 .. | *Myrtaceæ*, 57. |
| Stamens definite............ | *Onagraceæ*, 62. |
| 2. Fruit free, 1-celled, 1-seeded .. | *Anacardiaceæ*, 53. |
| 3. Fruit free, surrounded by the calyx, 2- or many-celled .... | *Lythraceæ*, 64. |
| 4. Fruit of free, simple, many-seeded carpels, standing in a circle. (Some Crassulaceæ are monopetalous.) ........... | *Crassulaceæ*, 66. |
| *b.* Seeds albuminous. | |
| * Ovary wholly or partly free. | |
| 1. Stamens opposite the petals ...... | *Rhamnaceæ*, 52. |
| 2. Stamens alternate, connected at the base with the petals .......... | (*Aquifoliaceæ*), 96. |
| 3. Stamens alternate, inserted on an hypogynous disk .............. | *Celastraceæ*, 51. |
| 4. Stamens alternate, perigynous, definite ......................... | *Saxifragaceæ*, 65. |
| 5. Stamens alternate, perigynous, numerous ...................... | (*Philadelpheæ*), 65. |
| ** Ovary quite inferior. | |
| 1. Æstivation of petals imbricated .. | *Haloragaceæ*, 63. |
| 2. Æstivation of petals inrolled, fruit a cremocarp ................ | *Umbelliferæ*, 78. |
| 3. Æstivation of petals valvate, fruit a berry...................... | *Araliaceæ*, 79. |
| 4. Æstivation of petals valvate, fruit a drupe...................... | *Cornaceæ*, 80. |

| | |
|---|---|
| II. Monopetalæ (ovary inferior). | |
| *a.* Anthers distinct, stamens adherent to the corolla. | |
| * Leaves opposite, with small intermediate stipules, or whorled with equal stipules | *Rubiaceæ*, 82. |
| ** Leaves opposite, without stipules. | |
| 1. Stamens opposite the petals | *Loranthaceæ*, 119. |
| 2. Stamens alternate with the petals. | |
| Ovary many-celled, seeds albuminous | *Caprifoliaceæ*, 81. |
| Ovary 1-celled, seeds albuminous | *Dipsaceæ*, 84. |
| Ovary 1-celled, seeds exalbuminous | *Valerianaceæ*, 83. |
| *** Leaves alternate, without stipules | *Campanulaceæ*, 87. |
| *b.* Anthers distinct, stamens hypogynous | (*Vaccinieæ*), 88. |
| *c.* Anthers coherent (syngenesious). | |
| * Flowers collected into capitula | *Compositæ*, 85. |
| ** Flowers solitary, irregular | *Lobeliaceæ*, 86. |

Some polypetalous Calycifloræ have the stamens inserted at the very base of the calyx, so as almost to resemble Thalamifloræ, as in Leguminosæ and Portulacaceæ. Apetalous genera and species occur here also, among the Leguminosæ, Rosaceæ, Myrtaceæ, Haloragaceæ, Rhamnaceæ, Celastraceæ, Lythraceæ, Portulacaceæ, Saxifragaceæ, Loranthaceæ, &c.

## C. COROLLIFLORÆ.

| | |
|---|---|
| 1. Flowers regular. | |
| ¶ (Stamens hypogynous, anthers dehiscing by pores | *Ericaceæ*, 88. |
| Stamens hypogynous, anthers opening by slits) | (*Rutaceæ*), 46. |
| ¶¶ Stamens adherent to the corolla, anthers dehiscing by valves. | |
| *a.* Compound ovary not deeply lobed externally. | |
| * Stamens alternating with the teeth of the corolla. | |
| 1. Stamens mostly 5, rarely 4 or 6. | |
| † Seeds exalbuminous. | |
| Embryo with plaited cotyledons | *Convolvulaceæ*, 102. |
| Embryo without distinct cotyledons | (*Cuscuteæ*), 102. |
| †† Seeds albuminous. | |
| Leaves opposite, without stipules | *Gentianaceæ*, 98. |
| Leaves opposite, with stipules | *Loganiaceæ*, 97. |
| Leaves alternate; capsule 2-celled (rarely many-celled) | *Solanaceæ*, 103. |
| 2. Stamens 4 or 1, corolla membranaceous | *Plantaginaceæ*, 91. |
| 3. Stamens 2 | *Oleaceæ*, 89. |

** Stamens opposite the teeth of the corolla.
  1. Ovary 1-celled, 1-ovuled ...... *Plumbaginaceæ*, 92.
  2. Ovary 1-celled, many-ovuled, with a free central placenta........ *Primulaceæ*, 93.

*b.* Ovary of 2 more or less united carpels (separating in the ripe fruit), with stigmas confluent.
  * Stigma discoid, free; stamens distinct, pollen pulverulent, æstivation of corolla contorted .................. *Apocynaceæ*, 99.
  ** Stigma 5-angled, anthers adherent to the stigma, pollen waxy, æstivation of corolla mostly imbricated ...... *Asclepiadaceæ*, 100.

*c.* Ovary deeply divided into 4 lobes, separating in the ripe fruit ............ *Boraginaceæ*, 104.

II. Flowers irregular; perfect stamens almost always less than 5, often didynamous.

¶ Ovary deeply divided into 4 lobes, separating when ripe ..................... *Labiatæ*, 105.

¶¶ Ovary not separating into lobes.
  *a.* Ovary 2–4-celled; seeds solitary or 2 in each cell ........................ *Verbenaceæ*, 106.
  *b.* Ovary 2-celled; seeds winged, many in each cell, exalbuminous ............ *Bignoniaceæ*, 108.
  *c.* Ovary 2-celled; seeds wingless, attached to hard placental processes, exalbuminous; bracts mostly large .......... *Acanthaceæ*, 107.
  *d.* Ovary 2-celled, seed albuminous ...... *Scrophulariaceæ*, 111.
  *e.* Ovary 1-celled, with parietal placentas, seeds albuminous.
    1. Leafless parasites .............. *Orobanchaceæ*, 110.
    2. Leafy plants; calyx half adherent.. *Gesneraceæ*, 109.
  *f.* Ovary 1-celled, with free central placenta; stamens 2, anthers 1-celled, seeds without albumen...................... *Lentibulaceæ*, 112.

Some Ericaceæ, Primulaceæ, Plumbaginaceæ, &c. have polypetalous corollas and hypogynous stamens. Some Primulaceæ and Oleaceæ are apetalous.

### D. MONOCHLAMYDEÆ.

A. With a distinct whorled perianth.

I. Flowers perfect (with stamens and pistils).

¶ Ovary superior.
  *a.* Ovary 1-celled, 1-seeded.
    * Leaves stipulate, ochreate ........ *Polygonaceæ*, 113.

** Leaves exstipulate.
1. Anthers bursting by lid-like valves .................. *Lauraceæ*, 117.
2. Anthers bursting longitudinally.
† Perianth long, tubular.
‡ Perianth forming a hard envelope to the fruit .......... *Nyctaginaceæ*, 114.
‡‡ Perianth not hardened.
Stamens in the points of the segments of the perianth. *Proteaceæ*, 123.
Stamens in the tube of the perianth .............. *Thymelaceæ*, 121.
†† Perianth short, segments separate nearly to the base.
Stamens opposite the segments.
Flowers with bracts ...... *Amarantaceæ*, 115.
Flowers without bracts .. *Chenopodiaceæ*, 116.

*b.* Ovary composed of several carpels, separate or combined into a 2- or many-celled ovary.
* Leaves exstipulate .............. *Phytolaccaceæ*, p. 339.
** Leaves stipulate................ *Ulmaceæ*, 127.

¶¶ Ovary inferior.
*a.* Ovary 1-celled .................. *Santalaceæ*, 120.
*b.* Ovary 3–6-celled.................. *Aristolochiaceæ*, 137.

II. Flowers diclinous.

¶ Ovary superior.

*a.* Ovary 1-celled, 1-seeded.
* Leaves exstipulate.
Perianth tubular .............. *Myristicaceæ*, 118.
Perianth short, segments deeply divided .................... *Chenopodiaceæ*, 116.
** Leaves stipulate................ *Urticaceæ*, 125.

*b.* Ovary many-celled.
* Leaves exstipulate.
Ovules suspended ............ *Euphorbiaceæ*, 124.
Ovules ascending.............. *Empetraceæ*, p. 346.
** Leaves stipulate.
Flowers in catkins ............ *Betulaceæ*, 131.
Flowers not in catkins ........ *Euphorbiaceæ*, 124.

¶¶ Ovary inferior.
* Leaves exstipulate.
Flowers in catkins.
Leaves alternate ............ *Myricaceæ*, p. 355.
Leaves opposite ............ *Juglandaceæ*, 129.

| | |
|---|---|
| ** Leaves stipulate. | |
| 1. Fruit in a cupule | *Cupuliferæ*, 130. |
| 2. Fruit naked. | |
| Fruit simple | (*Begoniaceæ*), 73. |
| Fruit multiple (sorosis) | (*Artocarpeæ*), 126. |
| B. With perianth in the form of bracts or abortive. | |
| I. Flowers hermaphrodite. | |
| Ovary 1-celled, 1-seeded; ovule erect | *Piperaceæ*, 134. |
| II. Flowers diclinous. | |
| *a.* Ovary 1-celled. | |
| * Leaves exstipulate; flowers in catkins | *Myricaceæ*, p. 355. |
| ** Leaves stipulate. | |
| † Ovules numerous, seeds comose | *Salicaceæ*, 132. |
| †† Ovules solitary or twin. | |
| Ovule erect | *Myricaceæ*, p. 355. |
| Ovule pendulous | *Platanaceæ*, 128. |
| *b.* Ovary 2- or more-celled. | |
| Fruits usually tricoccous | *Euphorbiaceæ*, 124. |
| Fruits indehiscent, seeds peltate | *Callitrichaceæ*, p. 359. |

*Apetalous flowers*

occur by abortion in the following Orders:

## A. PETALOIDEÆ.

| | |
|---|---|
| I. Ovary superior. | |
| *a.* Flowers perfect. | |
| * Seeds exalbuminous ................ | *Alismaceæ*, 155 |
| ** Seeds albuminous. | |
| 1. Perianth scale-like. | |
| Leaves pinnate or palmate ...... | *Palmaceæ*, 138. |
| Leaves grass-like................ | *Juncaceæ*, 145. |
| 2. Perianth petaloid. | |
| Fruit capsular, septicidal; stamens 6, extrorse .................. | *Melanthaceæ*, 144. |
| Fruit capsular, loculicidal; stamens 6, introrse.................... | *Liliaceæ*, 143. |
| Fruit a succulent berry .......... | *Smilaceæ*, 142. |
| *b.* Flowers diclinous .................... | (*Smilaceæ*), 142. |
| II. Ovary inferior. | |
| *a.* Flowers diclinous. | |
| Leaves with netted veins, seeds albuminous | *Dioscoreaceæ*, 141. |
| Leaves with parallel veins, seeds exalbuminous ........................... | *Hydrocharidaceæ*, 154. |
| *b.* Flowers perfect. | |
| * Flowers regular. | |
| 1. Stamens 3, extrorse .............. | *Iridaceæ*, 152. |
| 2. Stamens 6, introrse. | |
| Leaves hard, channelled, often scurfy; calyx and corolla mostly distinct. | *Bromeliaceæ*, 153. |
| Leaves soft; perianth uniform .... | *Amaryllidaceæ*, 151. |
| ** Flowers irregular. | |
| 1. Stamens 5 or 6 .................. | *Musaceæ*, 150. |
| 2. Stamens usually 1, free. | |
| Anthers 1-celled, filament petaloid. | *Marantaceæ*, 149. |
| Anthers 2-celled, filament not petaloid ..................... | *Zingiberaceæ*, 148. |
| 3. Stamens 1, sometimes 2, gynandrous. | *Orchidaceæ*, 147. |

## B. SPADICIFLORÆ.

| | |
|---|---|
| I. Flowers on a distinct spadix. | |
| *a.* Leaves mostly netted-veined, spadix enclosed in a large spathe, perianth absent, fruit succulent ...................... | *Aroideæ*, 140. |
| *b.* Leaves parallel-veined, broad and grass-like. | |
| * Stamens very short, perianth a few scales........................... | (*Acoreæ*), 140. |
| ** Stamens on long filaments, perianth scaly or hairy .................... | *Typhaceæ*, p. 369. |

| | |
|---|---|
| II. Flowers on a spadix reduced to a short peduncle, naked or surrounded by a spathe. | |
| *a.* Seeds exalbuminous | *Naiadaceæ*, 156. |
| *b.* Seeds albuminous. | |
| Stem and leaves blended in flat floating fronds | *Lemnaceæ*, p. 371. |

### C. GLUMIFLORÆ.

| | |
|---|---|
| I. Stem solid; leaf-sheaths tubular, not slit; glume 1, the flower in its axil; embryo basilar, within the albumen | *Cyperaceæ*, 158. |
| II. Stem fistular; leaf-sheaths slit; glumes mostly in pairs at the base of a spikelet, of 1, 2, or several flowers; embryo basilar, outside the albumen | *Graminaceæ*, 157. |

## Div. II. **Gymnospermia.**

| | |
|---|---|
| I. Stems branched, resembling Dicotyledons; leaves simple. | |
| *a.* Stems continuous. | |
| Fertile carpels several in a cone | *Pinaceæ*, 159. |
| Ovule solitary, surrounded by scales | *Taxaceæ*, 160. |
| *b.* Stems jointed | *Gnetaceæ*, 161. |
| II. Stems simple, resembling Palms; leaves pinnate | *Cycadaceæ*, 162. |

## Series II. **CRYPTOGAMIA—FLOWERLESS PLANTS.**

| | |
|---|---|
| Div. I. With stem and leaves distinct | ANGIOSPORÆ. |
| Div. II. With a thallus | GYMNOSPORÆ. |

## Div. I. **Angiosporæ.**

| | |
|---|---|
| 1. Plants with well-developed foliage. | |
| *a.* Fructification on the lower surface or edges, or on metamorphosed lobes, of the leaves. | *Filices*, 167. |
| 1. Sporanges with an annulus, dorsal or marginal, splitting irregularly | (*Polypodieæ*), 167. |
| 2. Sporanges without an annulus, dorsal, connate, splitting regularly by a ventral slit | (*Marattieæ*), 167. |
| 3. Sporanges with an obscure annulus, on metamorphosed pinnæ of the leaf | (*Osmundeæ*), 167. |
| 4. Sporanges without an annulus, distinct, 2-valved, on the margin of metamorphosed lobes of the leaf | (*Ophioglosseæ*), 167. |

*b.* Sporanges in the axils of imbricated leaves, or of bracts forming terminal spikes.

1. Creeping plants with elongated stems clothed with imbricated leaves; sporanges scattered or in spikes ........ *Lycopodiaceæ*, 164.

2. Plants with a corm-like stem bearing a tuft of sessile leaves with sporanges imbedded in their axils ............ *Isoëtaceæ*, 165.

*c.* Sporanges in stalked spore-fruits, arising from the creeping or floating rhizome near the bases of the leaves or petioles.. *Marsileaceæ*, 163.

*d.* Minute tufted or creeping plants with imbricated leaves and stalked or sessile urn-shaped or oval sporanges arising out of a vaginule or involucral sheath.

* Leaves mostly spirally imbricated; spores without elaters.

1. Capsules with a columella, with an operculum or indehiscent ........ *Bryaceæ*, 168.

2. Capsules with a columella, bursting by 4 lateral slits................ *Andræaceæ*, 170.

** Leaves distichous, capsules splitting into 4 valves, spores mixed with elaters *Jungermanniaceæ*, 171.

II. Plants with abortive foliage, consisting of simple or verticillately branched, jointed, fistular stems, with whorls of teeth (leaves) at the joints ....................... *Equisetaceæ*, 166.

III. Inconspicuous plants with a green thalloid frond with or without a midrib, bearing vaginulate sporanges immersed or stalked, or peltate receptacles with numerous sporanges.

1. Sporanges immersed or sessile, bursting irregularly, without elaters .......... *Riccieæ*, p. 426.

2. Sporanges as in Jungermanniaceæ (*vide suprà*) .......................... *Jungermanniaceæ*, 171.

3. Sporanges pod-shaped, 2-valved with a collumella......................... *Anthoceroteæ*, p. 424.

4. Sporanges numerous, on the underside of peltate stalked receptacles arising from the sinuses of the frond ............. *Marchantiaceæ*, 172.

IV. Aquatic plants with verticillately branched stems composed of tubular filaments, rooting; fruit consisting of solitary ovate spores (nucules) and globular 8-valved antheridia, attached to the whorled branches ...... *Characeæ*, 173.

## Div. II. **Gymnosporæ** (*Thallophytes*).

| | |
|---|---|
| I. Aquatic plants, with a coloured thallus, growing in water or on damp ground, leaf-like, filamentous or granular; fructification submerged | *Algæ*, 428. |
| 1. Thallus leaf-like, filamentous or incrusting, mostly red or purple; fructification scattered or in receptacles, consisting of spores, antheridia, and tetraspores | *Rhodospermeæ*, 174. |
| 2. Like the preceding, but olive or brownish | *Dictyotaceæ*, p. 434. |
| 3. Thallus leaf-like, cord-like, shrubby or filamentous, mostly olive or brown; fructification in conceptacles, collected in receptacles; conceptacles containing either spore-sacs or antheridia or both | *Fucaceæ*, 175. |
| 4. Olive-coloured or brown Seaweeds, with superficial or terminal spore-sacs producing zoospores with 2 cilia, one pointing forward, the other backward | *Phæosporeæ*, 176. |
| 5. Thallus usually green, mostly filamentous, or consisting of cellular masses imbedded in definite or indefinite jelly; fructification occurring in all cells, consisting of gonidia, active (zoospores) or motionless, and spores which are matured in parent cells after conjugation or fertilization by spermatozoids | *Confervoideæ*, 177. |
| 6. Filamentous plants, composed of jointed, sheathed filaments, simple or combined into bundles in a common sheath, often with a spontaneous oscillating motion | *Oscillatoriaceæ*, p. 53 |
| 7. Unicellular plants with angular or variously curved walls, free or associated in definitely arranged families, multiplied by fission, by zoospores, and by spores formed in sporanges resulting from conjugation | *Diatomaceæ*, 178. |
| *a*. Cell-wall membranous, contents green | (*Desmidieæ*), 178. |
| *b*. Cell-wall imbued with silica, contents brown | (*Diatomeæ*), 178. |
| 8. Globular or quadrangular hyaline microscopic aquatic bodies, containing green zoospore-like bodies whose cilia project from the surface of the common envelope and row it about | *Volvocineæ*, p. 440. |
| II. Plants growing over rocks, bark of trees, earth, &c., attached by hair-like fibrils; thallus leathery, crustaceous or pulverulent; fruit superficial or immersed in the thallus | *Lichenaceæ*, 179. |

III. Plants with a cottony thallus or mycelium devoid of chlorophyll or starch, growing in living or decaying organic matter; fruits distinct from the thallus, on a more or less developed receptacle .................. *Fungi*, p. 443.

1. Fungi with distinct fleshy, horny, or gelatinous fruit of definite form, consisting of a common receptacle developed in the interior of a dehiscent or indehiscent sac or peridium ........................ *Agaricaceæ*, 180.

2. Fungi with distinct fleshy, horny, or gelatinous fruit, consisting of a naked common receptacle bearing the spores...... *Exidiaceæ*, 181.

3. Fungi with a distinct or obscure fruit, often immersed in the supporting object; hollow conceptacles or open discoid receptacles lined with asci or stylospores.. *Sphæriaceæ*, 182.

4. Microscopic Fungi, forming mildews, &c., consisting of a flocculent thallus with numerous erect branched or simple filaments bearing acrogenous spores or sacs filled with endogenous spores ........ *Botrytaceæ*, 183.

# PART III.

# PHYSIOLOGY.

## CHAPTER I.

## PHYSIOLOGICAL ANATOMY OF PLANTS.

### **Sect. 1.** THE STRUCTURE OF PLANTS.

559. The Physiology of Plants is that department of Botany which treats of the phenomena of the *Life* of Plants, manifested in a series of changes taking place in the diverse parts of which each plant is composed.

These parts, as we have already seen (MORPHOLOGY, Chap. I.), are not simply fragments, combining to increase the bulk of the object (their size alone having no definite relation to that of the entire plant), but they are *instruments*, variously occupied in performing the different functions, the continuous operation of which indicates the existence of what we call Life. These instruments are called *Organs*.

The external characters of the Organs of plants, generally, have been described in the First Part of this work, and a summary indication of their functions has been conveyed by their classification under the heads of Vegetative and Reproductive Organs (§ 19). But the object of the Morphological chapters was to point out the conditions and relations of Form, as produced by the external shapes of the individual organs and their modes of combination. Here we have to examine the phenomena of Vitality, as displayed in the changes they present in the course of the Development, Growth, and Multiplication of Plants.

In the pursuit of this inquiry, it is soon found that we cannot go far without penetrating more deeply into the characters of Organs; for it is quickly perceived, as might be gathered even from the manifold variations on each type discovered in the study of Morphology, that mere external form is no sure indication of the nature of the vital functions performed by the organs of plants, and that the physiological character of an organ is dependent in great part upon its internal composition, or, at least, that the existence of a particular internal structure chiefly determines the function of an organ.

560. The physiological Organs of plants are themselves composed of a number of parts, which again exhibit a kind of completeness of their own, and a relation to the organs analogous to the relation of the latter to the entire plant. These ultimate parts of organic bodies, arrived at long before we reach the limits of the possible mechanical divisibility of the objects, constitute the "atoms," physiologically speaking, of plants, and are called the *Elementary Organs*.

When we proceed to subdivide by mechanical or chemical means the substance of the vegetative or reproductive organs, we resolve it into a number of microscopic vesicles and fibres; and then, if we attempt to divide these further, their distinctive character is lost, and they become mere fragments of vegetable matter, only certainly recognizable as of organic origin by their chemical composition. Under certain limitations, we may compare a plant, or an organ of a plant, to a crystal. Each has its definite character by which it is possible to distinguish it from any other object. But we might pulverize the crystal, and yet any one fragment of sufficient size for operation would display to the analyst all the chemical qualities of the entire crystal; and if we dissolved such a fragment and crystallized it upon a slip of glass, we should perceive by means of the microscope that it solidified into a miniature representation of the original crystal; moreover, if we then collected all the fragments and dissolved them, we might by careful evaporation reproduce a crystal exactly like that from which we started.

In Vegetables (as in Animals) the case is entirely different. When we cut a plant in pieces, the parts will differ not only in form but in structure, and bear no longer any recognizable relation to each other; we cannot reproduce the plant from them, and even the chemical examination of different fragments may give most diverse results—ultimate analysis alone, by which they are resolved into their mineral elements, arriving at the detection of a common bond among them, that of being formed of compounds which we only meet with in *organic matters*. Above all, in the act of subdivision, although this may be carried to a high degree in plants without destroying life (even sometimes within the limit of single organs), beyond a certain point it results in the annihilation of the especial force, the organizing or vital principle, by which the organs were made to combine their activity to produce the distinctive character as an independent individual object.

561. The diversities of form and consistence of the Elementary Organs give rise to all the differences of physical condition in the organs of vegetation and reproduction; and all those changes which collectively constitute the Life of plants depend on the combination of a multitude of minor operations which have their seat in the elementary organs, singly or as combined into tissues. The study of the Elementary Anatomy is therefore the only secure foundation upon which to build the Physiology of Plants.

562. The *elementary organs* of plants are all referable to one primary type, which is not only recognizable through a comparison

of the fully developed modifications, but is found to be the form in which all originate.

This fundamental organ of vegetable structure is called a *Cell*, and may be defined as a *closed sac composed of solid membrane and filled with fluid or semifluid matter.*

It must not, however, be overlooked that living plants can exist, at least for a time, without any bounding cell-membrane. The perfect cell is taken as the fundamental organ for convenience' sake, and because it presents a definite form; it is not to be regarded as the ultimate structural unit, because detached fragments of it are capable of independent existence under certain circumstances.

The form of the sac, and the consistence of the membrane of which it is composed, are points of subordinate importance; the condition of the fluid contents and their more or less heterogeneous character are likewise without influence upon the definition of the perfect *cell* as the primary element of the organic structure of plants; in which the absolutely essential characteristics are—the existence of a *membrane* or coat forming the boundary of the individual cell, and the *contents*, isolated by this boundary, on which depend the physiological efficiency of the cell.

563. The cell is the elementary organ of vegetable structure, but is not the smallest or most simple definite form in which organic matter may exist in plants. In the contents of cells we find *granules* of various kinds &c., and also *fibres*; the former, however, are not direct constituents of tissues, but occur only *among the contents* of cells, as more or less transitory conditions of assimilated matter; while the latter merely form parts of the structure of the cell-membrane.

Under the head of these granules, we comprehend chlorophyll-corpuscles, starch-grains, &c., together with filamentous bodies like the spermatozoids of the higher Cryptogamia &c. Many authors describe also what are termed *utricular* structures, minute cells within the cells; but considerable doubt exists as to the essentiality of the cavities which render some of the "granular" bodies vesicular, and, in any case, the coat of the hollow granules has no analogy to the wall of a true cell, since it is the active and efficient part of the "utricle." Further notice of these structures is reserved for the description of nuclei, chlorophyll, &c.

In regard to the *fibres*, those which were formerly regarded as distinct from the membrane of the cell are merely thickened portions of the wall, depending on what are called secondary deposits.

564. Plants of the lowest organization consist of the ultimate or elementary organs in their simplest forms, and may even be so simple as to consist of a single elementary organ or cell. A step higher, we find plants composed of a few cells connected together into a definitely arranged group in their earlier period of existence, and subsequently separating entirely into the constituent cells, each of which lays the foundation of a new colony.

Examples of Unicellular plants, in the stricter sense of the word, are furnished by the free *Desmidieæ* &c., such as *Closterium* (fig. 462, B, C)—of the families of essentially independent cells, also included under the name of Unicellular plants by some authors, by the geometrically grouped *Desmidieæ* (fig. 462, B, *a*) and the *Palmelleæ*.

565. By far the greater part of the species of plants are composed of an indefinite number of cells permanently combined together, forming what are termed the *tissues*. If the cells entering into the composition of a tissue are essentially alike, they form a *simple tissue*; if cells which have undergone modifications which give them an essentially diverse character are combined in an anatomically well-defined tissue, this is called a *compound tissue*.

In the Algæ, especially the simpler membranous or filamentous forms, we may readily see the uniformity of the character of the cells throughout the *thallus* (p. 427); the same uniformity prevails through the cells of such tissues as the pith of Dicotyledonous stems &c. But if we examine the wood surrounding this pith, or even the ribs running into the leaves, we find a variety of conditions of the elementary organs within the well-defined limits of these portions of woody tissue.

566. The *simple tissues* of plants are divisible again into two primary groups, according to the mode of union of the constituent cells. In proper *Cellular Tissues*, the cells, however firmly coherent, are only *in contact* by their walls, which form a persistent boundary between them. In a series of tissues most extensively developed in plants of high organization, the cells enter into closer relation, becoming confluent by the absorption of their contiguous surfaces, and thus converted into more or less extensive tubular bodies, which, in their various conditions, form what are called the *ducts* and *vessels* of plants. These constitute the *Vascular Tissues*.

What are called the *vessels* of plants are really compound elementary organs; but it is not requisite to enter into more minute distinctions here, since the phenomena of *fusion* of cells into such compound organs are not very varied in plants, and in all cases the composition of the structure from a number of distinct cells is very evident.

567. The tissues, simple and compound, enter into the composition of the Organs of Vegetation and Reproduction of Plants upon a certain general plan for any particular kind of organ, but under specially modified arrangements, referable to a progressive series of types, in the several large Classes of the Vegetable Kingdom.

## Sect. 2. The Cell.

### *Form and Magnitude.*

568. The shapes and sizes of the cells of plants are determined by causes of two kinds, namely:—their own laws of growth, which

are inborn and hereditary; and the favourable or obstructive influences which bear upon their development in each particular case.

As a general statement, it may be said that the primary form of the Vegetable Cell is that of a sphere; and that deviations from that type are more or less attributable to secondary influences, arising from the connexion of cells in coherent groups.

The spherical form is usually found in cells developed freely, *i. e.* not arising from mere subdivision of a preexisting cell. Thus we find embryonary cells and endosperm-cells in the embryo-sac of Phanerogamia, the spores of some Cryptogamia, together with many of the lower plants composed of one or few cells only, such as those of growing Yeast (fig. 468, A) &c., presenting the spherical as the original form. But by far the most frequently occurring spherical cells, such as many pollen-grains, spores, those in the pith of young shoots of Dicotyledons, of the pulp of fruit, &c., assume this form subsequently to the earliest stage of development, being placed in circumstances which allow them to expand freely according to their natural tendency.

569. The above general statement is subject to certain important exceptions, in which deviation from the typical form exists without any interference with the development of the cell according to its own laws; these are met with principally in the lower cellular plants, especially the Unicellular Algæ, in which we find single free cells assuming the most varied but specifically determinate forms.

Examples of this are offered not only by the *Desmidieæ*, but by the more unequivocally vegetable *Vaucheriæ*, *Botrydium* (fig. 462, E), and others.

570. The interfering influences above referred to are of two principal kinds, namely:—special directions assumed in the development, in obedience to a law regulating the structure of the organism, or of the tissue, of which the cell forms part; and obstruction to the possibility of expansion in certain directions, from the pressure of surrounding cells.

These influences are very fruitful in producing variety of form. The first kind is the most important, and determines the general form of the cell; the second in most cases affects merely the shape of its external surfaces. The form of the cells of fully developed tissues is usually the result of both kinds of influence combined.

571. In cells existing in combination we find three principal classes of forms, referable purely to the influence of the law of development:—(1) the *spheroidal*, obedient to the fundamental type; (2) the *cylindrical*, in which there is a more or less considerable tendency to elongate in the direction of a vertical axis; and (3) the *tabular*, in which there is an excess of development in the direction of the two transverse axes.

The *spheroidal* form presents every possible transition from the sphere (*Protococcus*, *pollen* of *Passiflora*, *Hibiscus*, cells of cortical parenchyma fig. 470, &c.), through the ellipsoidal (usual in longer or shorter forms in the subepidermal parenchyma of leaves), to the *fusiform* or *spindle-shape* (most abundant in the cells of wood and fibrous structures, fig. 471), and the truly *cylindrical*, either of moderate length (cells of Confervæ, fig. 465, &c.), or drawn out so as to become what is termed *filiform* (cotton, and other cellular hairs). The spheroidal form also passes gradually, especially in epidermal tissues, into the tabular form.

Fig. 470.

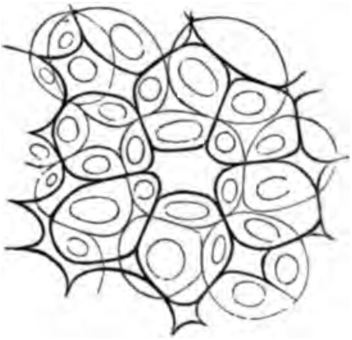


Fig. 471.

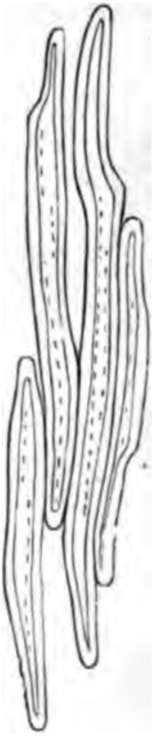


Fig. 472.

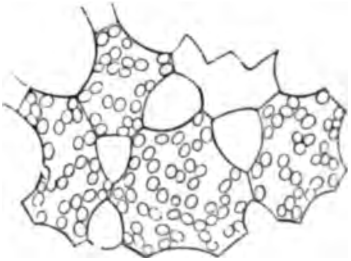


Fig. 470. Merenchymatous cells of the rind of *Euphorbia canariensis*. Magn. 100 diam.
Fig. 471. Liber-cells of *Cocos botryophora*. Magn. 50 diam.
Fig. 472. Parenchymatous cells from the leaf of *Orchis mascula*. Magn. 200 diam.

572. Secondary modifications of these forms arise chiefly either from partial cohesion in lax tissues, from irregular growth, or from pressure in densely packed tissues.

Thus the spheroidal form becomes, in lax tissues, an *irregular* spheroid in endless varieties (commonest of all in the parenchyma of leaves and rind of succulent stems), running out by degrees into lobed and finally *stellate* forms, by exclusive development of the free surfaces while the contiguous cells remain attached at a few points, *e. g.* in cells of the parenchyma of leaves and leaf-stalks of many Monocotyledons (fig. 472), *Musa*, *Sagittaria* (fig. 473), &c., and above all in the pith of Rushes (fig. 474), and the stems of various aquatic plants.

The mutual pressure of cells, commonly exerted in stems, in seeds, hard parts of fruits, &c., converts the spheroidal into *polygonal* forms, of which the more or less regular *dodecahedron* or *tetradecahedron*, giving an hexagonal section, and arising from equal pressure in all directions, is perhaps the commonest (pith of fully developed shoots of Dicotyledons, such as Elder, &c.), or *cubic*, found in woody fruits, &c. The cylindrical becomes under the same circumstances *prismatic*, either six-sided with flat ends, or with three rhombic faces at top and bottom, the common form of the cellular tissue of the stems of herbaceous stems (fig. 476), or 4-sided with flat ends, as in the medullary rays of Dicotyledons, or with conical or oblique ends, the common form of wood-cells. Less frequent are the forms of spores and pollen-grains, sometimes only temporary, sometimes permanent, arising from the development of four cells by segmentation of a spherical parent cell; these sometimes appear of the form of quarters of an orange, sometimes as *tetrahedra*, the curved surface forming the base of

Fig. 473.

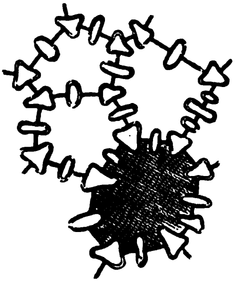


Fig. 474.

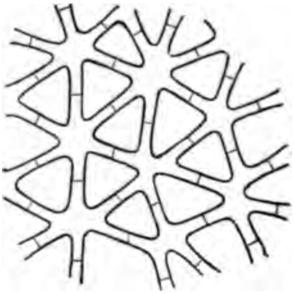


Fig. 475.

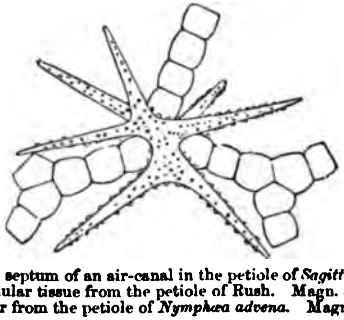
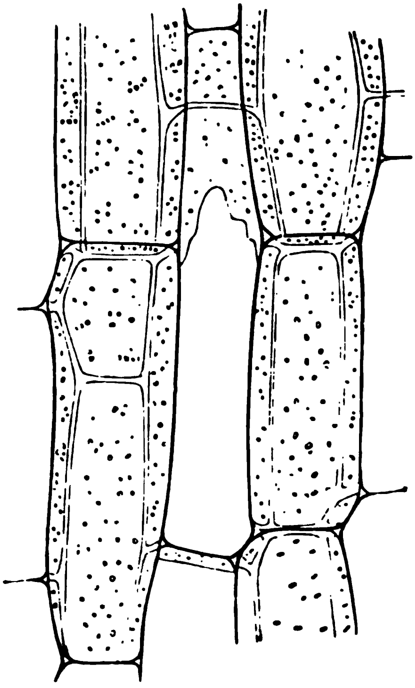


Fig. 473. Section of a septum of an air-canal in the petiole of *Sagittaria*. Magn. 300 diam.
Fig. 474. Stellate cellular tissue from the petiole of Rush. Magn. 300 diam.
Fig. 475. Stellate hair from the petiole of *Nymphæa advena*. Magn. 200 diam.

the pyramid. In the tabular forms of the cell, the mutual pressure generally confirms an originally rectangular figure, the *tabular* cells of epidermis and cortical structure being usually of quadrangular or polyangular figure, flat above and below (fig. 475); but in these we have sometimes a complication from expansion, under pressure, principally in certain directions, cells of epidermis of many plants exhibiting side-walls thrown into sinuosities following a particular pattern (fig. 478).

573. By far the great majority of cells in the higher plants originate in forms analogous to those produced by pressure, since they multiply by division, and the septa dividing two newly formed cells have ordinarily plane surfaces (fig. 477): a spherical cell forms two hemispherical cells &c.; a prismatic cell dividing perpendicularly, two half-prisms, or, if horizontally, two superposed shorter prisms, &c. As a general rule these cells have a tendency to assume the spherical (or cylindrical) form in their earlier stages of growth, while

Fig. 476.



Cells of the pith of *Acanthus mollis*, seen in a vertical section. Magn. 200 diam.

may trace this by making sec
from the growing point or *punctum*
the nascent cells are squarish ; lower

Fig. 477.

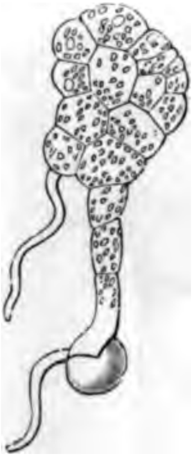


**Fig. 477.** Young prothallium developed fro
Magn. 200 diam.
**Fig. 478.** Epidermis of the lower surface of t
(*a*). Magn. 200 diam.

rical, while when full-grown they are
from cylindrical to prismatic takes pla
stems and shoots ; but in succeeding
division of preexisting cells exhibit

the other hand, the spores of Fungi afford examples of extremely minute dimensions, such as $\frac{1}{4000}$ to $\frac{1}{6000}$ of an inch. The cylindrical cells of wood are not uncommonly $\frac{1}{60}$ of an inch in length; liber-cells sometimes from $\frac{1}{12}$ to $\frac{1}{4}$, or $\frac{2}{3}$ of an inch (Flax). Hairs composed of one or more cylindrical cells, and the cylindrical cells of some of the Confervæ, especially *Vaucheria*, *Bryopsis*, &c., and *Chara*, also attain longitudinal dimensions to be measured in inches, while their diameter is estimated in hundredths of an inch.

### *The Cell-wall.*

575. In all young cells the wall is of membranous nature, and in many cases it always retains this character. While young this membrane is freely permeable by water, elastic and flexible. As the cell-wall grows older it becomes altered in consistence and firmer, opposing a greater obstacle to the entrance of water into its substance, independently of any great increase of thickness, as we see in cork-cells; when it increases in thickness it may remain soft and flexible, or become very dense, but in such cases it generally remains tolerably freely permeable by water, even when most dense, while the softer kinds absorb water so readily that they swell up considerably when wetted.

Membrane of living cells always appears to contain water as an essential part, almost like the water of crystallization in hydrated salts. When dried, cells contract more or less; and many phenomena of bursting of fruits, sporanges, &c. are the result of the tearing down of weak regions of cellular tissue by the contraction of firmer tissues in drying. Cellular tissues with soft thick membrane, like those of the Algæ &c., contract in drying so as to cause the shrivelling of the structure. All such tissues absorb water when wetted, and swell up again, but do not in all cases reassume their original flexibility. Cells of wood, liber, &c. also expand when wetted: but the expansion takes place in a direction transverse to their axes, and they usually contract in the longitudinal dimension as they swell laterally. Hence, although wood and fibrous structures swell in water, it is only in the direction *across* the *grain*, and cordage simultaneously *contracts* in the direction of the fibres.

Diluted sulphuric acid and alkaline solutions cause a swelling of the membrane of most cells, of which advantage is sometimes taken in woven fabrics to render the stuff closer in texture. By soaking in an alkaline solution, the single fibres are made to swell so as to come more completely into contact and fill up the interstices.

576. Primary, unaltered cell-membrane is colourless; subsequently it becomes coloured, usually of a tint of brown, apparently by infiltration of substances formed in the contents, since by boiling the membrane of old, deep-brown tissues with nitric acid, or with solution of potash, the colouring-matter may be extracted.

577. The original membrane of a newly formed cell is, as far as we have the means of perceiving it, a homogeneous layer of substance, the *porous* nature of which is only to be concluded from the fact of

its permeability, no visible pores being revealed by the most perfect microscopes we possess.

It is important to note this homogeneity of the primary cell-wall, as the membrane almost always becomes marked with dots and lines, indicating inequality of thickness, as it becomes thicker.

578. This primary membrane appears to have the property of growing by what is called intussusception of molecules, since it expands to accommodate the increasing contents of the cell in cell-growth, without any indication of *structure* necessarily accompanying the expansion.

No better example of this can be mentioned than the growth of the pollen-tube of Phanerogamia, which sometimes acquires a length of 2 or more inches (*Cactus*) without ever departing from the homogeneous pellicular structure.

Cell-membrane, however, may increase in size by expansion, as we see in the cell-division of *Œdogonium*, in which a thickened ring of accumulated cellulose is stretched out by the elongating cell and becomes a thin membranous coat to the latter.

The molecular structure of cell-membrane has been studied by Nägeli, who, from his researches on the constitution of the membrane of the starch-grain by means of polarized light, comes to the conclusion that all organic substances are composed of *crystalline* molecules grouped in a definite manner. When dry the molecules are without interspaces; when moist, each molecule is surrounded by a thin film of water. Nägeli further supposes that each molecule is made up of a number of atoms, similar to or identical with the atoms of the chemist. The molecules are of different sizes; those portions of the structure richest in water have the smallest molecules. The molecules themselves are of the nature of crystals with two optic axes.

579. The walls of almost all cells soon exhibit a departure from the original simple condition, arising from the formation of new

Fig. 479.

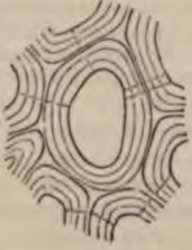


Fig. 480.

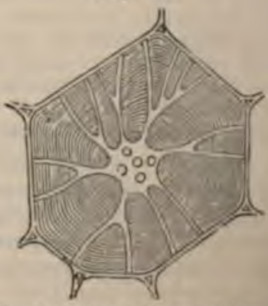


Fig. 479. Transverse section of liber-cells of *Cocos botryophora*. Magn. 200 diam.
Fig. 480. Transverse section of a thick-walled cell from the pith of *Hoya carnosa*. Magn. 500 diam.

lamellæ, more or less resembling the primary membrane, all over, or over particular parts of the inside of the primary membrane. These are distinguished as *secondary layers* (figs. 479, 480). The consistence of these layers, and the mode in which they are disposed, produce the most important diversities of character of the walls of fully developed cells.

The laminated condition of cell-membrane may be well observed in simple cellular structures by treating fragments of *Cladophora glomerata*, or other large Confervoid, with diluted sulphuric acid. The laminæ are very visible in cross sections of the cells of wood and liber after these have been boiled for a short time in nitric acid.

580. Besides the primary membrane and the secondary layers, we find in certain cases a kind of envelope which has been variously explained by different authors. The filaments of some Confervoids (*Spirogyra*, fig. 465), of *Desmidium*, &c., the families of cells of *Palmelleæ* and *Nostochineæ*, are surrounded by a coat of gelatinous consistence, outside the proper cell-membrane. This appears to be produced by the softening and swelling up of the parent cells (of many generations) of the cells which are surrounded by such envelopes.

These gelatinous coats are apparently analogous to the *intercellular substance*, as it has been called, to be mentioned hereafter.

581. Another layer is characteristic of many cell-membranes which are destined to protect the subjacent tissues, or their own contents, from the action of the atmosphere, namely those of epidermal cells and of pollen-grains and spores. These exhibit a superficial pellicle, of varied character as to thickness, texture, and marking, which pellicle appears subsequently to the first formation of the cell. This, like the gelatinous coat just described, is a structure altogether of secondary character, but is distinguished from the ordinary secondary layers of thickening by its position on the *outside* of the cell-wall.

It is still a moot question whether these pellicles are secreted by the primary membrane on the outside, or are formed by transformation of the outer laminæ of the primary membrane itself, whose place is then taken by some of the outer secondary layers. This subject will be more dwelt upon under the head of the *cuticle*.

582. The secondary formations on the inside of the cell-membrane may (1) correspond in character to the primary wall, in which case the cell-wall is simply thickened by new lamellæ; or (2) the new layers applying themselves equally over the wall, leave certain parts bare, which appear as *dots* or *pits* of various forms when viewed from the inside (figs. 481, A, B); or (3) they are applied only over parts which form peculiar patterns upon the primary wall, and appear, when of sufficient thickness, like *fibres* adhering to it, spiral, annular, or connected into a kind of network.

Those secondary layers which resemble the primary wall, although uniformly deposited, present in certain cases an appearance as though their molecules were arranged in a spiral order, since fine spiral streaks may sometimes be detected, after treating them with acids and by other means, and many of them are apt to tear in a spiral direction. The excessively delicate spiral marking here referred to (seen in liber-cells of *Vinca* (fig. 483) and most Apocynaceæ and Asclepiadaceæ, in wood-cells of *Pinus*, in the cell-membrane of *Hydrodictyon*, &c.) must not be confounded with a deceptive appearance resembling a much coarser spiral striation produced by treating the membranes of Confervæ, the parenchyma-cells of *Orchis*, *Cucurbita*, &c. with sulphuric acid, where the appearance often results from the irregular convolutions of the swollen lamellæ of the cell-wall.

Fig. 481, A.

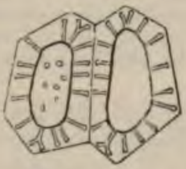


Fig. 481, B.

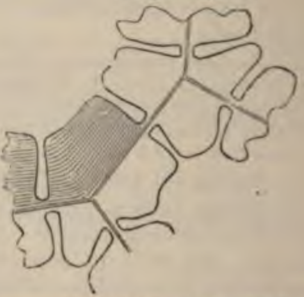


Fig. 481, A. Section of cells of the endosperm of a Sago-Palm. Magn. 200 diam.
Fig. 481, B. Laminated cell-walls of the cells in A. Magn. 500 diam.

583. The uniform kind of secondary layers are sometimes accumulated at one side (fig. 484), or in the angles of cells (fig. 485): thus they are much thicker on the side of epidermal cells next the air; and they fill up the angles of the cells of the fleshy endosperm of many seeds, the cells of the *collenchyma* found beneath the rind of Chenopodiaceæ, and the cells of the leaves of *Nymphæa*, of some Jungermanniaceæ, &c. There is reason to believe that, in some instances, the cell-wall thickens at certain seasons and becomes thinner at others; but this appearance may arise from an alternately swollen and contracted state, and not from absorption and re-deposition.

These will be spoken of again under the heads of *epidermis* and *intercellular substance.*

584. The deposits leaving spots of the primary membrane bare form what are called *pitted*, or, less properly, *porous* cells. They occur on the walls of most cells of the parenchymatous structures of the higher plants, in the form of round spots (fig. 476) where the still membranous cell-wall is thinner. In wood-cells, in liber-cells,

and the greatly thickened cells of fleshy endosperms, hard seed-coats, &c. the application of a great number of secondary layers upon the wall, always leaving those spots bare, converts the pits into canals running out from the contracted cavity to the primary wall (figs. 480, 481).

The marks are really always *pits* at first, as may be seen by colouring the cell-membrane with iodine. But in old wood-cells they appear sometimes to become holes, by the absorption of the primary membrane which formed a kind of diaphragm over the outer end.

These pitted markings may be circular, oval, or elongated, transversely

Fig. 484.

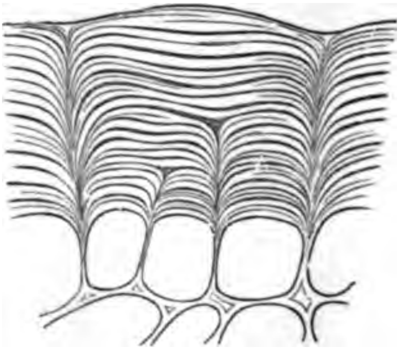


Fig. 482.

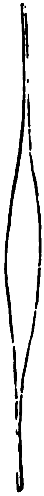


Fig. 483.

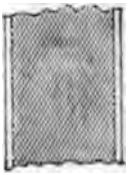


Fig. 486.

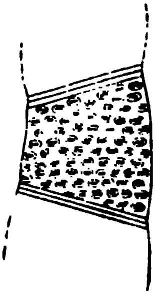


Fig. 485.

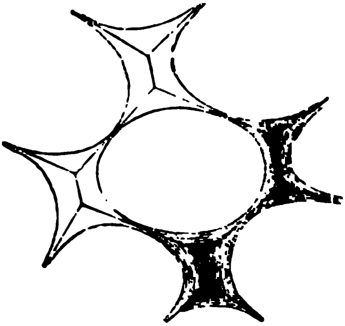


Fig. 482. Liber-cell of Periwinkle. Magn. 75 diam.
Fig. 483. Fragment of the cell in fig. 482, magnified 300 diam. (The spiral lines on the opposite side of the cell show through and cross.)
Fig. 484. Vertical section of epidermis of *Viscum album*, with many thickening layers. Magn. 400 diam.
Fig. 485. Transverse section of cells of the petiole of *Nymphæa alba*, showing the laminated wall. Magn 300 diam.
Fig. 486. Fragment of a pitted duct of *Laurus Sassafras*. Magn. 200 diam.

or more or less obliquely, so as to approach to the appearance of slits. Sometimes the later secondary deposits do not extend quite to the edge of the aperture in the earlier layers, and the successive layers may so retreat from this edge that the canal becomes at length funnel-shaped; in this case the pit, when seen in front, presents a double outline, one corresponding to the outer end, the other to the inner and wider end (fig. 486).

This condition may be further complicated by the existence of a lenticular depression between the contiguous outside walls of pitted cells, as in Coniferæ (fig. 487). The outline of this depression gives the appearance of a circle surrounding the central pit. Schacht, however, asserts that the pit is a real perforation, and, further, that in the very young condition the lenticular cavity between two adjacent cells is divided into two compartments by a thin longitudinal partition, which is the primary deposit of the two cells. The lenticular cavity is formed by the resorption of this deposit, and a communication established between the two adjacent cells. These areolated pits (or maculæ, as Schacht calls them) are not, as was once supposed, confined to the Coniferæ; but they are universally found throughout that group with a regularity of disposition and constancy of occurrence not known elsewhere.

Fig. 487.

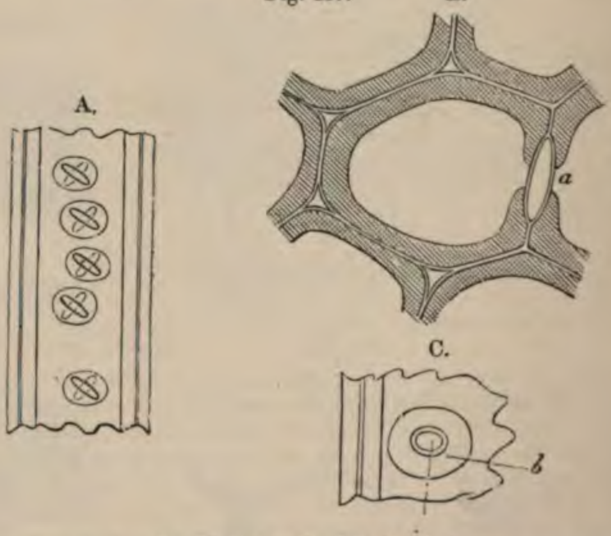


Fig. 487. Pits or "Glands" of Coniferæ.
A. Part of a wood-cell of *Ginkgo biloba*, in vertical section. Magn. 500 diam. B. Transverse section of a wood-cell of *Pinus Pinea*: *a*, a bordered pit, or "gland." Magn. 1000 diam. C. Fragment of the wall of a wood-cell of *Pinus Pinea*, with a bordered pit or "gland:" *a*, the pit; *b*, the large ring, caused by the lenticular interspace (*a*). Magn. 1000 diam.

585. A further complication of the pitted structure has, moreover,

been described by Von Mohl as occurring in the *vasa propria* of the vascular bundles of Monocotyledons, and in the thin-walled cells, layers of which alternate with the long woody fibres in the liber of Dicotyledons. In these cells, which that author calls "latticed" or "clathrate" cells, the membrane which forms the diaphragm closing large pits is marked with an excessively delicate network, apparently formed of fibres applied upon the primary membrane. This occurs not only in the pits of the side-walls, but in those which are found on the septa between cells standing one above another.

This discovery is of much interest, and is likely to draw more attention to the liber-structures, which have been neglected by anatomists, but which may possibly take an important share in the distribution of the elaborated sap.

586. The "fibrous" secondary layers may present the form of a single spiral band, running from one end of the cell to the other, and with the turns of the spire quite close, or more or less distant (fig. 488); or the spiral band may be double, triple, or even consist

Fig. 488.

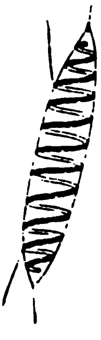


Fig. 490.

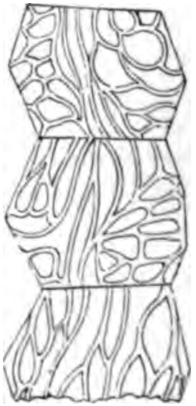


Fig. 489.

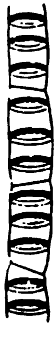


Fig. 488. Cell from the sporangium of *Equisetum arvense*. Magn. 250 diam.
Fig. 489. Cells from the sporangium of *Marchantia polymorpha*. Magn. 250 diam.
Fig. 490. Cells from the leaf of *Sanseviera guineensis*. Magn. 400 diam.

of six or more parallel bands. Very often these spiral secondary deposits are sufficiently elastic to allow of their being stretched out, the comparatively thin primary membrane to which they adhere giving way at the interstices.

In the cells of the coat of the seed of *Collomia*, the primary membrane becomes, during the ripening of the seed, converted into a substance which softens and swells up in water; so that when this structure is wetted, the spiral fibre springs out, opening its coils widely like a wire spring.

587. The *annular* thickenings (fig. 489) are less common than the spiral, but occur sometimes in the same cell, and also in association with the next kind, the reticulated. The rings are generally at some little distance apart.

588. The *reticulated* secondary layers may be uniform over the wall of the cell, or irregular (fig. 490), which is more frequent, since the ordinary cause of the reticulated appearance is the formation of vertical connecting bars between rings or spiral coils, at the angles of the cells; when this occurs very regularly, a ladder-like arrangement results, giving what is called the *scalariform* structure, especially frequent in the vascular structure of Ferns (fig. 491).

Fig. 491.

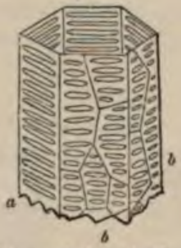


Fig. 492.

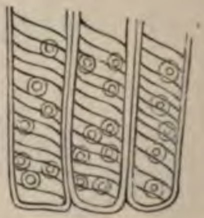


Fig. 491. Fragment of a scalariform vessel of a Tree-Fern: *a*, walls in contact with other vessels; *b*, *b*, walls in contact with cells. Magn. 200 diam.
Fig. 492. Wood-cells of Yew; vertical section. Magn. 300 diam.

The connecting bars of the reticulated and scalariform cells must not be supposed to originate after the rings or spirals; they are contemporaneously developed; and the diversities in the closeness of the coils of cells are likewise original peculiarities of the deposits. The statement that the turns of spiral coils are opened by longitudinal growth of the primary membrane to which they adhere seems to be founded on speculative notions.

The spiral structure of secondary deposits is beautifully seen in the elaters of *Jungermannia* and *Marchantia*, in the cells of the aërial roots of epiphytic Orchids, in the cells of the wood of Cactaceæ, and in the spiral vessels of the veins of the leaves and leaf-stalks of Monocotyledonous plants, such as the Hyacinth, Narcissus, *Musa* (which presents as many as 20 parallel bands), shoots of Elder, leaf-stalks of garden Rhubarb, Strawberries, &c., also in the petals of delicately organized flowers. Annular cells are well seen in the sporanges of *Marchantia* and other Liverworts, and in many of the structures just mentioned with spiral and reticulated cells. The scalariform marking is most regular in Ferns.

589. The scalariform thickening approaches very nearly to the more regular forms of the dotted thickening above described, so that

the spiral-fibrous and the dotted forms appear as the extremes of an analogous kind of structure.

In many wood-cells, especially in root-structures, the reticulated or scalariform cells have the meshes so small that they become in fact pitted cells.

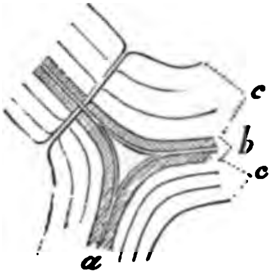
In some cells both kinds of thickening occur, so that it is convenient to distinguish *tertiary* layers. In the wood-cells of the Yew (fig. 492), of the Lime, and other plants the secondary layers are pitted, and a tertiary deposit subsequently appears in the form of a spiral fibre.

The pits on the walls of contiguous cells correspond, and they do not generally occur opposite intercellular spaces, or on the outside of epidermal cells; but exceptions occur to both these rules, to the latter especially in the leaves of *Cycas*. The first rule has much influence on the marking of the large cells forming part of *ducts*, which are often in contact with several cells, one above another, and with parenchyma-cells, other ducts, or with intercellular spaces, on different sides. In the wood-cells of Coniferæ, the peculiar bordered pits occur only on the sides parallel to the medullary rays, not on the internal and external walls.

590. Cell-membranes, including the secondary layers, are composed of the substance called *cellulose*, which is one of a class of organic compounds intimately connected as regards chemical constitution, but presenting remarkable physical differences. Of these compounds the most important are:—*sugar* and *dextrine*, soluble in cold water, and occurring in solution in the cell-sap; *starch*, insoluble in cold, but softening and swelling into a mucilage in boiling water, and found in the form of granules in the cell-contents; and *cellulose*, insoluble in cold or boiling water, alcohol or ether, obstinately resisting the action of alkaline solutions, but soluble in strong sulphuric acid, and forming the permanent solid parts of vegetable structure.

591. Cell-membranes, composed of pure cellulose originally, undergo changes at subsequent periods which alter, in a marked manner, their behaviour towards chemical reagents; and it is not at present certainly ascertained what is the real cause of the series of modifications which they present. If we compare the membrane of a nascent cell, of thick-walled parenchyma, the solid and often dark-coloured walls of the cells of old heart-wood, of liber-cells, the very resistant membranes of corky tissues, and the layers of gelatinous or cartilaginous consistence so abundantly developed in the larger

Fig. 493.



Wall of the cells of the liber of Cocos: *a*, primary membrane; *b*, oldest secondary layers; *c*, more recent secondary layers; the layers marked *b* are strongly incrusted. Magn. 600 diam.

Algæ, we meet with extremely different characteristics, for the explanation of which different views are entertained. On the one hand it is said that the cellulose produced in the formation of the original membrane or layer of thickening becomes gradually converted into different but related chemical compounds; on the other, that the cellulose layers become impregnated by foreign substances, gradually infused into them from the fluid contents, such substances being distinguished by the name of *incrusting* matters (fig. 493). A third view is that of Frémy, who considers that there are several kinds or modifications of cellulose, and, moreover, that those vegetable structures formerly considered to be made up exclusively of cellulose, contain matters of a different chemical composition.

Cellulose, as found in the organized condition of cell-membrane, appears to behave somewhat differently to chemical reagents according to the state of aggregation of its particles (that is to say, its density); for nascent cell-membranes will in many cases assume a violet or even a blue colour when treated with a strong solution of iodine and washed with water, like starch. The same is the case with some of the semigelatinous layers of thickening met with in the endosperm or cotyledons of certain seeds (called *amyloid*), and, moreover, in the cell-structures generally which have been treated in the way described below, to remove the so-called "incrusting matters." But as a general rule, cellulose does not take a blue colour with aqueous solution of iodine, unless some other agent, especially sulphuric acid, is applied at the same time. A solution of iodine in chloride of zinc brings out a blue colour in fully developed cell-membranes, still more readily than the sulphuric acid with iodine. These reagents readily affect newly formed tissues in general; and the more delicate kinds of cellular tissues are permanently sensitive to them. But after a time the thicker cell-membranes, and especially those of woody tissues, the cartilaginous structures, and the tissue of epidermis and bark, no longer become blue, but only yellow or brown with the above reagents; and it is the real cause of this alteration which is the subject of the difference of opinion above referred to.

By maceration for several hours, or boiling for a minute or two, in nitric acid for woody and cartilaginous tissues, in strong solution of potash for epidermal and corky tissues, bringing the cells to a point where they still exhibit all their structure, but are bleached and softened, then washing them with water and applying iodine, a blue colour is produced like that appearing in nascent cellulose, or in tolerably new tissues under the influence of sulphuric acid.

It remains to be ascertained whether these processes alter the composition of the cell-membranes, or merely remove infiltrated matters of nitrogenous composition. The latter view is supported by the fact that, in imperfectly prepared objects, some of the more resisting layers appear *green*, which would seem to result from an optical combination of the blue of the cellulose with the yellow of an infiltrated matter. At the same time it must be noticed that the cellulose is brought into a condition approaching that of starch, only normal in nascent membranes and in the semisolid deposits of "amyloid" above mentioned. Frémy, as above stated, considers that there are other substances besides cellulose entering into the composition of vegetable cell-walls. *True cellulose* forms the cell-wall of the cellular tissue of bark, fruits, roots, &c., and is soluble in ammoniacal oxide of copper. *Paracellulose* is found in the cells of the pith, the epidermis, the medullary rays, &c.; it is soluble in the copper solution, but only after special treatment. *Fibrose* is the constituent of the wood-cells, and is insoluble in the copper solution, except after special treatment, but soluble in strong sulphuric acid. *Vasculose*, the substance of which vessels are formed, is insoluble in hydrochloric and sulphuric acids and in the copper solutions, but soluble in boiling caustic potash.

592. Cell-membrane in most cases contains a certain amount of inorganic matter; but this is probably attributable in general to its being saturated with the watery cell-sap, in which various salts exist in solution. In particular cases, however, there is a special deposition of inorganic substance in the walls of cells—as, for instance, in the Grasses and the Equisetaceæ, and the Cane-Palms (*Calamus*), where the epidermal structures are so loaded with silex that they not only acquire a hard texture, rendering them harsh to the touch, but, when the organic matter is destroyed by burning, a complete skeleton of the tissue remains, entirely formed of silex. The siliceous coats of the *Diatomeæ* afford another striking example.

It is not yet clearly made out whether the silex is here deposited in a layer upon the cell-membrane, or interpenetrates its substance; but the latter is probably the real state of the case. The pericarp of some plants, as *Lithospermum*, contains lime, in what form it is not certain; but the carbonate of lime incrusting the cells of many species of *Chara* is clearly a mechanical deposit upon the outside of the membrane.

593. The membranous wall of the vegetable cell is ordinarily a permanent structure: forming the "skeleton" of plants, it usually remains entire until the decay or destruction of the organism in which it exists. But we have already mentioned that it becomes absorbed or dissolved, ultimately, at particular points, as at the contiguous end-surfaces of those cells which become fused together to form vessels or ducts; and in the case of the layer closing the outer ends of the canals of the pits or wood-cells, a similar destruction of the primary membrane seems to occur. A phenomenon of this kind is distinctly presented in the large spiral-fibrous cells of *Sphagnum* (fig. 494), where the walls of old cells are found perforated by large round orifices, produced by the separation of circular pieces of the cell-wall, and in the cells of the leaves of *Leucobryum glaucum* (fig. 495). In the cells of the Confervoids producing zoospores, the wall breaks open at definite places to allow these to escape, exhibiting small lateral or terminal orifices in *Conferva* (fig. 465, c, *d*) &c., or breaking quite across by a circular slit in *Œdo-*

*gonium.* In this last genus the cell-wall breaks across in the same way in cell-division, to allow the new cells to expand; and in one of the *Palmelleæ* (*Schizochlamys*) the wall of the parent cell splits off in segments every time a new generation of cells is formed.

Fig. 494.

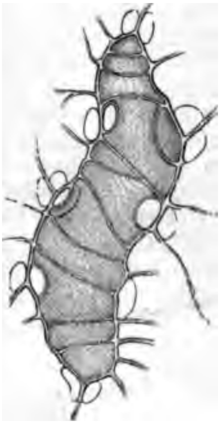


Fig. 495.

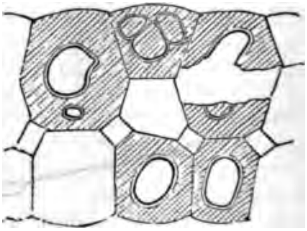


Fig. 494. Cell of the leaf of *Sphagnum cymbifolium*, with annular fibres and orifices in the wall. Magn. 400 diam.

Fig. 495. Porous cells of the leaf of *Leucobryum glaucum*; vertical section. Magn. 400 diam.

In the formation of the ultimately free cells composing pollen-grains and the spores of the higher Cryptogamia, the cells are liberated from the parent cells by solution of the wall of the latter. A still more curious phenomenon occurs in the process of *conjugation*, where two cells coalesce by complete union of their walls. The last cases appear related in some degree to the origin of the gelatinous coats of the *Palmelleæ* and other Confervoids, which are probably produced by the disintegration of the walls of parent cells, which become softened, and swell up as the new generations of cells are formed in their interior.

The origin of cellulose is not clearly determined; it seems most probable, however, that it is derived from the starch, sugar, inuline, or similar materials contained in the protoplasm of the cell, as mentioned in succeeding paragraphs.

### *Contents of the Cell.*

594. The solid cellulose structures forming the persistent mass of vegetable tissues may be regarded as a skeleton or framework; for the vital and chemical phenomena exhibited by plants all depend, in the first instance, upon operations which have their seat in the interior of the cells. The careful investigation of the cell-contents

is consequently of primary importance in the study of Vegetable Physiology.

The fundamental importance of the matters within the cell is not only demonstrated by what we are enabled to observe taking place in the interior of living cells, but, in certain of the lower plants, the vitalized contents actually emerge from their confinement in the shell of cellulose (as the so-called *zoospores*), and exhibit in the course of their subsequent conversion into closed motionless cells exactly the same power to form new cell-membrane as takes place in ordinary cell-division.

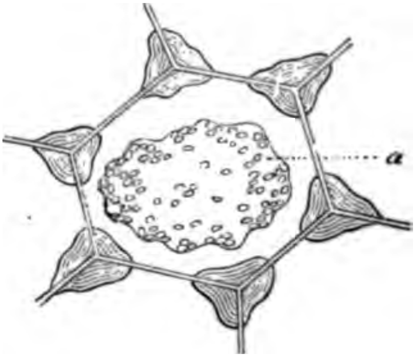
595. The contents of the cell are partly more or less solid, partly fluid. When substances exist dissolved in the cell-sap, they are frequently out of the reach of microscopic observation, on account of the minute quantities in which they exist, or from the want of suitable reagents to ascertain their presence; among these are the vegetable alkaloids and similar products. The sugar, dextrine, mineral salts, &c., dissolved in the watery cell-sap, do not readily admit of examination in this way. The fluid colouring-matters, essential or fixed oils, resins, &c., on the contrary, are readily observed, on account of their distinct physical and chemical characters. This is still more the case with mineral or organic salts which are sufficiently abundant to crystallize in the cell.

596. But by far the most important of the contents of cells are certain organized structures which are regularly met with in the cell-contents, either universally or, with certain definite exceptions, at particular epochs of the life of cells. These are the *protoplasm*, with the *primordial utricle*, the *nucleus*, *chlorophyll-corpuscles*, and *starch-granules*.

597. In all young growing cells we meet with a tough mucilaginous fluid, colourless or with a yellow tinge, and frequently of more or less granular character, which increases with the age of the cell. This substance is called the *protoplasm*.

The *primordial utricle* is the outer film of the protoplasm, from which it differs only in its greater density. It is coloured yellow by iodine, and is applied intimately to the inner surface of the cell-

Fig. 496.



Transverse section of cell of *Jungermannia Tayleri*: *a*, the primordial utricle contracted from the action of alcohol. Magn. 500 diam.

membrane of young cells, persisting in the cells of tissues which are concerned in the reproduction of cells or the performance of the functions of assimilation &c., but disappearing at a comparatively early period in cells which acquire fibrous or pitted woody secondary layers.

This structure is not always readily discoverable in living cells, on account of its close apposition to the cell-wall, but it may be detected by the application of a weak solution of iodine, which colours it brown, and soon causes it to contract and separate from the cell-membrane (fig. 496). The contraction is disadvantageous in some cases, if it go very far, as the layer becomes applied upon the inner cell-contents. The structure is very well seen by placing portions of the green tissue of leaves &c. (which retain the primordial utricle after acquiring their full size), of the pulp of fruits, the leaves of Mosses or Liverworts (fig. 496), or the filaments of Confervoids, in alcohol, or treating them with dilute nitric or muriatic acid. The primordial utricle then separates from the cell-wall without becoming much discoloured.

598. The *primordial utricle*, lining the entire wall of the cell, forms a kind of *sac*; but it is *not* a *membrane* in the same sense as the proper cell-wall, since, although it presents a certain cohesion and resistance to the penetration of water, it is not merely flexible, but *ductile*, and capable of moulding itself into new external forms, the sac, in cell-division, becoming constricted into two or more portions without wrinkling. When the zoospores of the Algæ escape from the parent cell, the primordial utricle forms the external boundary of the structure of the zoospore, which has a definite form in each case.

Were it not for this definite form of zoospores, we might compare the consistence of the primordial utricle to that semifluid condition of glass in which the glass-blowers mould it. This peculiar state of organized substance is exactly parallel to the substance of *Amœba*, the soft part of Sponges, &c. in the Animal kingdom.

599. In young cells, such as those in the cambium-layer of stems, in the growing parts of leaves, &c., the protoplasm nearly fills up the cavity, or at all events occupies all the space not filled by the *nucleus*. By degrees, as the cell expands, vacuolar spaces make their appearance in the protoplasm, filled with watery cell-sap; and the protoplasm is thus transformed into a kind of froth, which is often finally displaced so entirely by the cell-sap that it forms merely a layer applied against the primordial utricle.

In some cells, especially of the lower plants, we may detect more than one of these parietal layers of protoplasm.

These changes are readily traced in very young hairs, where they are observed without much disturbing the natural condition of the structure (fig. 497). Movements in the protoplasm, rendered evident by the movement of the granules floating in it, occur in many plants, probably in all, and are attributed by some to contractility of the protoplasm, by others to alternate turgescence and emptying of certain portions of the protoplasm.

600. In the protoplasm of most young cells, and persistent through life in the parenchymatous structures of some plants, as of the Orchidaceæ, occurs the globular or lenticular body called the *nucleus* of the cell, or *cytoblast* (figs. 497, *n*, & 498). This appears to be a mass of substance identical in its character with the substance of the protoplasm, and it mostly presents the appearance of a central cavity or vacuole containing one or more small granules called *nucleoli*.

Fig. 497.

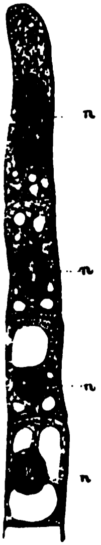


Fig. 498.

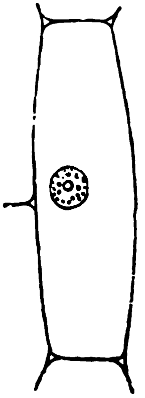


Fig. 497. Upper end of a young hair of the stamen of *Tradescantia*, showing the cells in various stages of development: *n*, *n*, nuclei. Magn. 400 diam.
Fig. 498. Cell with a nucleus, from the stem of *Orchis mascula*. Magn. 400 diam.

The nucleus is not usually found in Fungi or Lichens; and many Algæ are likewise unprovided with it.

601. The nucleus probably originally occupies the centre of all nascent cells where it exists, the interspace between it and the primordial utricle being filled up by protoplasm. When the vacuolar displacement of the latter by watery cell-sap takes place, the nucleus, if persistent, is usually carried to one side of the cell, and comes into contact with the inner boundary of the primordial utricle. Sometimes, however, it remains suspended in the centre of the cell by cords of tough protoplasm, stretched from a layer of protoplasm coating the nucleus to that which lies upon the primordial utricle. The

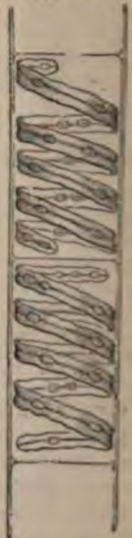
cords of protoplasm radiating from the nucleus are the persistent boundaries of the vacuolar spaces of the "honeycombed" protoplasm.

The gradual vacuolation of the protoplasm and the transfer of the nucleus to the side of the cell may be well seen in the hairs of the stamens of *Tradescantia* (fig. 497). In *Spirogyra* and *Zygnema* the nucleus remains always suspended in the middle of the cell by the protoplasmic cords. The ultimately parietal nucleus of the hairs of *Tradescantia* exhibits radiating cords, the protoplasm here being in process of absorption. In *Vallisneria*, and in *Œdogonium* and other Confervoids, the nucleus becomes imbedded in the continuous parietal layer of protoplasm which lies upon the primordial utricle. The nucleus has the property of breaking up and, as it were, disappearing for a time, to reappear in the form of two or more new nuclei of larger size than the original nucleus. This process occurs in the formation of the pollen in the embryo-sac of Phanerogamous plants &c.

602. In all parts of plants which have a green colour we find the cell containing in its cavity structures quite distinct from the cell-wall and from the primordial utricle, in which the green colouring-matter resides. The ordinary form of these is that of globular or spheroidal corpuscles, which appear in greater number and of darker green colour in proportion to the intensity of solar light to which the tissue may be exposed. In a few cases the green colouring-matter is found in the form of annular or spiral bands (*Draparnaldia*, *Spirogyra*, fig. 499), or of reticulated cords (*Cladophora*), of mucilaginous consistence, adhering to the inside of the primordial utricle. In some Confervæ the green colouring-matter appears diffused through a portion of the protoplasm in the form of very minute granules. In many unicellular Algæ, in the gonidia of Lichens, &c. the green colouring-matter is uniformly distributed throughout the cell, and is not separable from the rest of the protoplasm.

The *chlorophyll-corpuscles* are of soft consistence; and their colour is extracted by ether, alcohol, and various acids. They consist of protoplasmic colourless substance mixed with colouring-matter. The former may exist by itself unmixed; but the colouring-matter is never found separate in nature. They appear usually solid and homogeneous when young; subsequently they often contain starch-granules in the interior; and not unfrequently they become vacuolated like protoplasm when exposed to the direct action of water.

Fig. 499.



Cells of a filament of *Spirogyra*, with spiral green bands. Magn. 200 diam.

Frémy states that the green colour of chlorophyll is due to an admixture of two substances, one yellow and the other blue, called respectively *phylloxanthine* and *phyllocyanine*; but others think that the blue substance is a modification of the yellow, brought about by the agency of acids. Our chemical knowledge of chlorophyll, however, is at present incomplete. It is to be expected that spectrum-analysis will ultimately reveal much of what is now obscure. The principal appearances observed hitherto are the constant presence of an absorption-band in the red portion of the spectrum. In concentrated solutions another band may be seen in the green. Stokes notes a similar band in the yellow. Herapath indicates the frequent presence of three bands in the red, orange, and green respectively, and of four bands in the red, orange, green, and blue portions respectively. These variations are probably due to different colouring-substances mixed with chlorophyll.

The chlorophyll-corpuscles are probably formed from the protoplasm of the cell breaking up into distinct globular corpuscles, or distributing itself according to patterns, as above indicated, upon the cell-wall. When newly formed, in young cells, they are almost colourless, and appear in the vicinity of the nucleus and in the layers or streaks of protoplasm; and we not unfrequently meet with protoplasmic corpuscles which differ from chlorophyll-corpuscles only in the absence of the green colour. The development of chlorophyll takes place thus:—In the young cell the protoplasm is colourless and disposed in a thick layer around the inner wall of the cell; in this appears first a yellow colouring-matter; and then the inner portion of the protoplasm splits up into polygonal portions, each of which becomes a grain of chlorophyll. The outer portion of the protoplasm forms the so-called primordial utricle. In other cases the protoplasm accumulates round the nucleus. *Vacuoles* are formed in it, and break up the substance of the protoplasm into granules. In this latter case more uncoloured protoplasm is left after the formation of the chlorophyll than in the preceding case.

The destruction or decay of chlorophyll shows itself first in the change of colour from green to yellow or orange, or, in the case of the spores of Algæ, red. This red colour is assumed at the time when the spores come to rest; when active vegetation again commences, the green colour is restored. In the case of leaves at the fall, the grains of chlorophyll diminish, then disappear and give place to highly refracting granules of an orange colour, which are the remnants of the disorganized chlorophyll, and to which the colour of leaves in autumn is due. While these processes are going on, the starch and the protoplasm are dissolved and stored away in the permanent tissues. In plants kept in the dark Gris noticed that the chlorophyll-grains slowly and gradually become smaller, lose their starch and their colour, till at length nothing but a number of minute amorphous granules remain. Some plants, such as *Selaginella*, some Ferns, &c., resist the deprivation of light much more than others; but in the case of quickly growing plants, two or three days obscurity suffice to disorganize the chlorophyll.

The protoplasm (with the primordial utricle), the nucleus, and the chlorophyll-granules are all substances containing nitrogen and closely allied to albumen; they are more or less coagulable by heat, alcohol, and acids, and soluble in caustic potash.

The principal tests are the following, though it must be remembered that their action is masked by the colouring-matters of the cell, and that they are not in all cases manifested in living, but only in dead cells:—Iodine gives a brown or yellowish tinge to these structures; ammoniacal solution of carmine tinges them pink. When treated with nitric acid, and subsequently with ammonia, a yellow tint is formed, indicating the presence of xantho-protein; when soaked in a solution of sulphate of copper and afterwards treated with potash, a violet colour is produced in the protoplasm and chlorophyll; but this has not been observed in the case of the nucleus. It must be remembered that the solubility of protoplasm in acids and alkalies depends not only on the strength of the solvent, but also on the condition of the substance at the time of the experiment.

603. Another still more common organized structure found in the cell-contents is the *starch-granule*, which appears to occur throughout every class of plants except the Fungi.

Starch-granules are perhaps most frequently of globular form when young; but when they acquire any considerable size their form usually diverges from this, and presents very remarkable varieties, often attributable to the conditions in which they grow. Full-grown starch-granules are not homogeneous, but marked with striæ indicating the concentric laminæ of which they are composed. These laminæ are alternately of denser and softer consistence, and surround a commonly more or less excentric point, usually of very small size (fig. 500), which often appears solid when the starch-granule is fresh, but forms a minute cavity, frequently running out into a few radiating cracks, when the starch-granules are dry.

The granules occur either singly or collected in masses of definite shape, forming compound granules (fig. 501); very often they exist in the interior of chlorophyll-corpuscles or bands, or imbedded in *the* protoplasm lining the cell-wall. In certain tissues they fill the

Fig. 500.

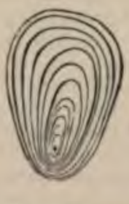


Fig. 501.

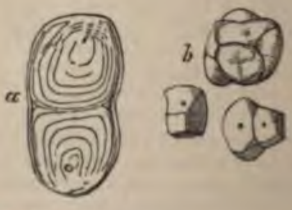


Fig. 500. Starch-granule of Potato. Magn. 400 diam.

Fig. 501. Compound Starch-granules: *a*, a double granule from the Potato; *b*, grouped granules and two fragments, from the rhizome of *Arum maculatum*. Magn. 400 diam.

cavity of the full-grown cell, and in some cases so densely that they become moulded into polygonal forms by mutual pressure.

Starch-granules are commonly unaffected by cold water; but when crushed, the inner layers will sometimes absorb it and swell up. Boiling water causes them to swell up into a jelly, losing all trace of their laminated structure—as do also diluted sulphuric acid and solution of potash.

Iodine colours starch-granules violet, indigo-blue, or deep blackish blue, in proportion to the degree of concentration in which it is employed. By means of dilute sulphuric acid, starch may be converted into dextrine and glucose. Modern researches have shown that starch consists of two substances intimately combined, one of which, *granulose*, is more soluble in saliva than the other, *cellulose*; and the action of iodine is also different in the two cases.

Great discussion has taken place at different times of late years both as to the structure and the mode of development of starch-granules. There is no question that they are formed of a number of concentric laminæ, which increase in density from within outwards. Their substance is hardly distinguishable from that condition of cellulose where the cell-membrane swells into a gelatinous substance with dilute sulphuric acid, or even sometimes with water, and takes a more or less decided blue colour with iodine alone. With regard to their mode of development, they appear to be formed by the deposition of successive layers of starch-substance, by protoplasm, in the interior of vacuolar cavities formed on the protoplasmic matter of the cell, either while this exists as a colourless mucilaginous matter, or after it has become more highly organized into chlorophyll-corpuscles. Starch-granules, in fact, appear to be formed by secretion on the inside of a utricle of protoplasm, exactly in the same way as the cellulose wall of the cell is secreted on the outside of the primordial utricle.

Fig. 502.

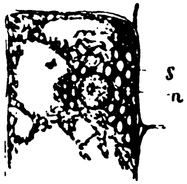


Fig. 503.

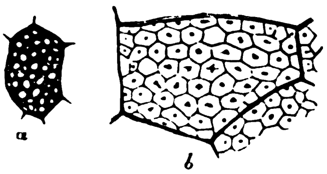


Fig. 502. Part of a cell of the stem of the White Lily: n, nucleus, surrounded by protoplasm in which starch-granules (s) are being developed. Magn. 400 diam.

Fig. 503. Starch of Maize: a, section of a young cell of the seed, with nascent starch-granules imbedded in protoplasm; b, section of a full-grown cell with the starch-granules in contact and become angular by mutual pressure. Magn. 200 diam.

This mode of development is well illustrated in the formation of starch-granules in the cords of protoplasm which have ceased to circulate, in many herbaceous Monocotyledonous stems, as that of the White Lily (fig. 502), &c.,—by the appearance of single or several starch-granules in old chlorophyll-corpuscles, or in the substance of the bands of *Spiro-*

*gyra* (fig. 499), &c. Still more strikingly is it shown in the development of the starch-granules which ultimately densely fill the outer cells of the endosperm of Maize, where they are at first free from each other, imbedded in a collection of protoplasm filling the cell (fig. 503, *a*), and, as they expand, come into contact and almost displace all the protoplasm, which remains only as a reticulation of slender threads (fig. 503, *b*). A similar reticulation of protoplasm-threads remains on the walls of the cells of the Potato-tuber after its starch-granules are formed.

The origin of the compound granules, in pairs, fours, or very many compacted together into a mass, moulded together by mutual pressure on their contiguous surfaces, is readily explicable, since we often find several isolated nascent granules in one chlorophyll- or protoplasm-corpuscle: as the granules increase in size they come into contact, but remain bound together by the mass of protoplasm in which they lie. Such granules (found in the corms of *Crocus* and *Arum* (fig. 501, *b*), in the Oat, and more or less abundantly in many other Monocotyledonous plants) are mostly simply coherent, so that they may be separated by slight pressure. But it is not uncommon to find twin granules enclosed by external layers common to both (fig. 501, *a*).

604. Starch is a temporary structure of the cell-contents; it is accumulated during active vegetation, and is abundantly deposited in the tissues of many organs which remain at rest during certain seasons. In the recommencement of growth it is dissolved, in consequence of the formation of diastase (which converts the insoluble starch into soluble dextrine), and the assimilated substance is applied to the formation of permanent structure.

Starch-grains are almost universally present in chlorophyll, from which, indeed, they are formed. This opinion differs from that of Mohl, but is supported by the discoveries of Sachs and Gris, the former of whom shows conclusively that the starch is developed from the chlorophyll under the influence of light: if light be excluded, no starch is formed, what is already formed disappears, and is again formed when the chlorophyll is once more subjected to the influence of light. Without chlorophyll no starch is formed; it may, however, be stored up in cells containing no chlorophyll, but is brought there from the cells in which it is formed.

Starch-grains are disintegrated or dissolved when growth is about to take place, in two ways—either locally (when the grains present a worm-eaten appearance), or uniformly over the whole surface.

605. In certain plants starch-granules are absent in those situations where they are generally abundant, being replaced by a substance of analogous composition, called *inuline*. This has been found especially in the roots and tubers of the Compositæ. It is not clear whether it occurs dissolved in the cell-sap or in granules mixed with the protoplasm. As it has no special reactions giving distinct colour, like starch, it cannot be detected except by chemical analysis.

606. *Aleurone* exists in the form of roundish colourless granules pitted on the surface or even presenting facets like those of crystals.

The granules are for the most part about equal in size; but here and there occurs one much larger than the rest and which is remarkable for the rapidity with which it dissolves in water; hence it escapes observation under the microscope when the tissues are examined, as they usually are, in water. Aleurone is insoluble in oil, alcohol, and ether; hence it is found in practice better to immerse the preparation in a drop of oil, in order to see the aleurone. Aleurone is coloured brown by iodine; and the inner portions of the grain assume a brick-red colour after soaking for some minutes in a solution of nitrate of mercury: hence it is considered to be albuminoid in character; but the nature, mode of formation, and chemical history of this substance all stand in need of further investigation.

607. The fixed oils, which occur abundantly in many seeds and fruits, are easily distinguished in the cell-contents on account of their forming isolated globules, merely suspended in the watery cell-sap, which strongly refract light, and can be made to run together into large globules by pressure and by the application of ether.

The oil-globules occur mostly in organs prepared for a season of rest, as in the endosperm (Cocoa-nut) or cotyledons (Almond) of seeds, or in the pericarp (Olive) of the higher plants—also sometimes in tubers, as in those of *Cyperus esculentus*. Among the lower plants oil is especially abundant in the resting-spores of the Algæ, taking the place of the starch-granules existing during active vegetation.

608. Sugar, dextrine, gum, and similar substances dissolved in the watery cell-sap are not capable of detection by the microscope, since the quantities in which they exist are too small to alter sufficiently the refractive power of the liquids; and we have no colour-test for them.

The *gummy matters* of plants (which swell up in cold water and form a slimy mass) are in many cases parts of the cellulose tissues themselves, as is the case in the seed-coat of Linseed, the Quince, &c. and the gum of Tragacanth, which latter consists of the collenchymatous tissue into which the pith and medullary rays of the stem are gradually converted. They result from the abundant deposition of secondary layers in that state of the "cellulose" compound which is intermediate between cell-membrane and dextrine, just as the "amyloid" of the secondary layers of the cells of some Lichens is an intermediate condition between cellulose and starch. *Bassoine* and *arabine* are formed in a similar manner, from the disorganization of the cellulose matters; hence these materials are to be looked on as excrementitious.

609. The bright *colours* of the parts of flowers are produced by substances usually dissolved in the watery cell-sap; sometimes, however, solid corpuscles or utricular structures are found swimming in coloured cell-sap.

In young tissues of flowers the colouring-matter may be observed to be formed gradually in the vacuoles of the protoplasm, and, as the cells expand, increasing in quantity until the separate portions coalesce and fill the whole cavity of the cell. This is well seen in the coloured hairs of the stamens of *Tradescantia*.

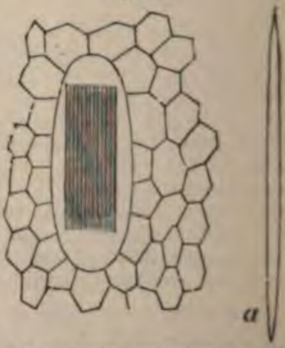
The colouring-matters of flowers admit of being grouped in two series, the cyanic series and the xanthic series, with green as an intermediate colour: thus, starting with greenish blue, the cyanic series passes through blue, blue-violet, violet, violet-red to red; the xanthic series, on the other hand, passes from green to greenish yellow, yellow, orange-yellow, orange, orange-red to red. The cyanic colours are usually in solution; the xanthic colours are usually solid. It very rarely happens that the colours of the two series are met with in the same flower; hence, though Dahlias and Roses of almost all hues are now to be seen, a true blue tint has never been seen in either; and there are numerous illustrations of this fact in gardens. The various tints of colour are produced either by the interposition of colourless cells between those containing coloured juices or by the superposition of cells with different colouring-matter one over the other. Thus an orange tint would arise from the superposition of yellow cells over red, and so forth. White is produced either by a very dilute coloured solution or by the presence of air in comparatively large quantities in the tissues. The velvety appearance of the petals of many flowers is due to the fact that the epidermal cells are raised in the form of small conical elevations like the pile of velvet, and the play of light thereon gives rise to the appearance above mentioned.

610. Essential oils are readily distinguishable when they exist in quantity suspended in the cell-sap, or entirely filling the cell; sometimes, however, they exist in such small proportions as to be undistinguishable, as is the case in many scented petals.

The essential oils are developed, like the fluid colouring-matters, in vacuoles of the protoplasm, resolved in time into one large cell-cavity bounded by the layer of the protoplasm lining the primordial utricle. The oily matters, caoutchouc, resins, &c. are usually found in compound cellular organs, *glands*, *ducts*, &c., to be mentioned presently, under the head of *Tissues*.

611. The watery fluids traversing the tissues of growing plants, in consequence of the evaporation from the leaves and the continual absorption by the roots, necessarily contain various inorganic salts dissolved in them. Moreover certain organic acids, such as oxalic, malic, tartaric, &c., are always formed in the processes of vegetable digestion. All these substances and their compounds are, for the most part, dissolved in the cell-sap; but in most of the higher plants we find, in certain cells of the parenchymatous tissues, crystals

Fig. 504.



Acicular crystals (raphides) in a cell of *Polyanthes tuberosa*, magnified 400 diam.: *a*, a single crystal more magnified.

of definite composition, either scattered or collected into groups of definite form. These crystals are called *raphides* (fig. 504).

It is not clear whether the raphides are to be regarded as a secretion or as an excretion—that is, as substances useless or noxious to the plant, laid by in an insoluble form. The latter seems more probable. The Polygonaceæ (for example, the Garden Rhubarb) form abundance of oxalic and other organic acids, and they always contain a quantity of bundles of raphides composed chiefly of oxalate of lime; in old stems of Cactaceæ, the substance of the parenchyma is rendered quite gritty to the touch by crystals of oxalate and phosphate of lime; the Musaceæ contain crystals of sulphate of lime, &c.

612. Crystals usually occur free in the cavity of the cell; but in some plants, especially in the Urticaceæ, we find them accumulated on a clavate process, formed of cellulose, developed from the side-wall of the cell; these are called *cystolithes.*

These curious structures are well seen in the subepidermal cells of the leaf of *Ficus elastica* and other species—also in *Parietaria*, the Mulberry, &c.

Other important substances, such as the vegetable alkaloids and the great number of organic acids usually associated with them, exist either dissolved in the cell-sap, intermixed with the protoplasm, or diffused in the solid cell-structures as impregnating or incrusting substances. With regard to these, microscopic investigation has not hitherto afforded any information.

## Sect. 3. COMBINATIONS OF CELLS.

### *The Tissues.*

613. The simplest mode of combination of cells is that which is met with in a large number of the Algæ of low organization, where the cells are associated for a time in what are called *colonies*, the members of which are more or less completely independent of each other in physiological respects, but morphologically represent parts of a determinate whole; while ultimately they separate, each to lay the foundation of a new colony.

Examples of this may be seen in the grouped *Desmidieæ*, like *Pediastrum* (fig. 462, B, *a*), the *Diatomeæ* &c., and in the *Palmelleæ*; to this head is also referable the structure of some of the filamentous Confervoids, Volvocineæ (fig. 462, D), and *Hydrodictyon.*

These groups of cells are either held together by simple attachment at certain points of their surfaces, as in the *Desmidieæ*, *Hydrodictyon*, *Diatoma* (fig. 462, B, *c*), &c., or by their being enclosed in a gelatinous common envelope (resulting from the expansion or the decay of parent-cell membranes), as in the *Volvocineæ*, *Palmelleæ*, and *Nostochineæ.*

614. *Tissues* properly so called consist of collections of cells of uniform character permanently combined together by more or less complete union of their outer surfaces.

615. The tissues are distinguished into kinds according to the form of the cells, the character of the cell-membrane, and the manner in which the cells are connected together.

Where the cells are roundish or elliptical, the tissue is called *parenchyma*; and this is called imperfect or perfect accordingly as the constituent cells have interspaces between them or are closely packed so as to leave no intercellular spaces. Where the cells are much elongated, the tissue is called *prosenchyma*, and the constituent cells are known as fibres. Cartilaginous tissue is known as *collenchyma*; and two other kinds are characterized by peculiar modes of combination of the cells, viz. felted tissue (*tela contexta*) and vascular tissue.

The milk-vessels (*cinenchyma*) appear to be formed out of intercellular passages, and not by fusion of cells, like the spiroid vessels: hence they do not constitute a true cellular tissue; otherwise they would come under the head of vascular tissues.

616. *Imperfect parenchyma* (*merenchyma*) is composed of cells with more or less rounded surfaces connected into a lax tissue, necessarily presenting abundant intercellular passages and spaces. The cells are tolerably uniform globular or oval (*a*), or lobed, and connected at few points, leaving wide intercellular passages between them (*b*); in other cases the cells are more or less stellate, and leave large spaces between them (*c*).

The form *a* is common in all young organs of the higher plants, especially in the rind and the pith (fig. 470), in the pulp of fruits, &c.; *b* is very characteristic of the lower stratum of the internal substance of leaves (fig. 472); *c* occurs in the stems and leaf-stalks of aquatic plants, in the pith of Rushes (fig. 474), &c.

617. *Perfect parenchyma* is composed of cells bounded and united together by plane surfaces; where the cells are regular polyhedra, of about equal size, the tissue is (*a*) *regular parenchyma*; if the size is unequal and the forms unlike, the tissue becomes (*b*) *irregular parenchyma*. Certain modifications of regular parenchyma have received distinct names, viz.:—(*c*) *prismatic parenchyma*, where the cells are 6-sided prisms with pyramidal ends; (*d*) *muriform parenchyma*, where the cells are square or oblong, with the long diameter horizontal, and packed like bricks in a wall; and (*e*) *tabular parenchyma*, where the cells are flattened from above downwards.

The form *a* is abundant throughout all classes of plants, and is well seen in fully developed pith of Dicotyledons (fig. 476); *b* is even more common in the soft parts of plants (fig. 477); *c* is met with in the herbaceous stems of Monocotyledons, and in the upper part of the diachyma of leaves, also in a woody condition in the testa of various seeds; *d* is characteristic of cortical structures, and may be seen in cork, periderm of Birch, the rind of the rhizome of *Tamus* &c., also in the medullary rays of Dicotyledons; *e* occurs specially in the epidermal cells.

Merenchyma and parenchyma in their various modifications run into one another by countless intermediate conditions.

618. *Prosenchyma* is composed of cells elongated greatly in one direction, and attenuated to a more or less acute point at each end, forming what is called a *fibre*. These fibres are necessarily united for the most part by their lateral surfaces, and their ends are insinuated into the spaces between those lying above and below them.

We distinguish in prosenchyma two modifications—(*a*) *woody fibre*, composed of spindle-shaped cells of moderate length, and (*b*) *liber*, composed of very long slender cells which are occasionally slightly branched.

Woody fibre is the main constituent of the trunks of Dicotyledons; its cells are mostly of rectangular section, and the walls become greatly thickened with age. *Liber*, the fibrous substance of the bark of Dicotyledons, a principal constituent in the fibro-vascular bundles of Monocotyledons (fig. 471), and of the fibrous husks of fruits, &c., is composed of very long cells, whose membranes are of a peculiar toughness, even when greatly thickened; their section is commonly roundish (fig. 479) or hexagonal. The peculiar tenacity of the vegetable fibres, Flax, Hemp, &c., arises from the forms and mode of union of the liber-cells of which they consist; the "grain" of wood is likewise determined by the direction of the long axis of the prosenchymatous cells of which it is composed.

*Conducting cells* are long cylindrical cells, placed one over the other, and not tapering at the ends, and are supposed to be channels for the passage of the nutrient fluid.

619. *Collenchyma* is cellular tissue which has acquired a cartilaginous or horny texture by its cells becoming greatly thickened by secondary layers of a substance softening or swelling up in water, or on the addition of weak sulphuric acid.

The lamination of the cell-walls is often invisible until after maceration; so that the tissue looks like a mass of homogeneous substance, excavated into cavities, or like a collection of cells with abundant intercellular

Fig. 505.

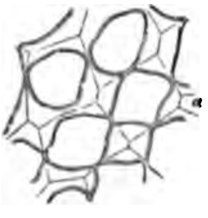


Fig. 506.

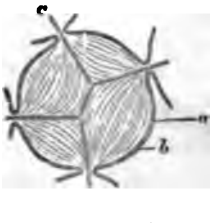
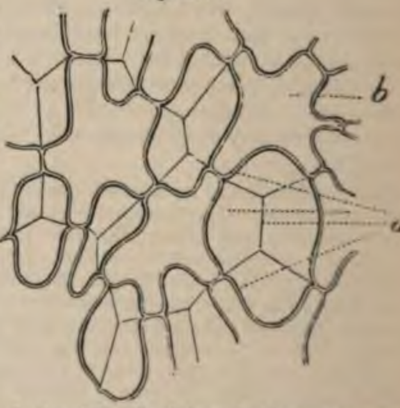


Fig. 505. Transverse section of collenchyma-cells of the stem of Beet: *a*, thickened cell-wall. Magn. 400 diam.

Fig. 506. Section of the junction of four cells (*a*) of fig. 505, treated with hydrochloric acid: *a*, lamina bounding the cavity of the cells; *b*, swollen secondary layers; *c*, primary membrane. Magn. 400 diam.

substance. A solution of chromic acid also serves to show the laminated structure; but if used too strong, it dissolves the intercellular substance. This tissue occurs in the rind of many herbaceous plants, as Chenopodiaceæ (figs. 505 & 506), *Cucurbita, Nymphæa* (fig. 485), and in the pith and medullary rays of the species of *Astragalus* (forming "tragacanth"); and to the same head may be referred the substance of fleshy endosperms (fig. 507), and also the cartilaginous thallus of the larger Algæ.

Fig. 507.



Section of the cells of the seed of *Sophora japonica*: *a*, thickened cell-walls; *b*, cavity of the cells (bounded by a double line). Magn. 400 diam.

620. *Tela contexta* is composed of elongated cylindrical cells united end to end into filaments, and either simple or branched laterally, interwoven irregularly into a kind of felted mass.

This tissue occurs in the thallus of Lichens, forming the internal or medullary substance, also in the thallus of some Algæ. The mycelium of the Fungi is likewise composed of felted cellular filaments forming a free cottony mass (fig. 468, B & D).

621. *Vascular tissue* is formed by the fusion of perpendicular rows of cells; by the absorption of their contiguous walls they become converted into continuous tubes of more or less considerable length.

When the constituent cells have spiral-fibrous secondary deposits, they are usually of prosenchymatous form, and they overlap each other so that the lines of union are oblique; sometimes these spiroid tubes are distinguished as *vessels* from those formed of the usually shorter, mostly wider, and more or less flat-ended cells which have pitted walls, and which are called *dotted* or *pitted ducts*.

Another kind of vessels characterized by thin walls, often with the latticed marking (§ 585), are distinguished as *vasa propria*.

The dotted ducts are connected with the spiroids through the scalariform vessels, but in their extreme forms are very unlike, and are found in very different situations.

622. The vessels, like the cells (§ 586), may be *spiral*, *annular*, *reticulated*, or *scalariform*. The constituent cells may be long or short; in the latter case the vessels are sometimes called *moniliform*. The spiral-fibrous structure often remains when the primary membrane is absorbed at the surface of junction, so that the consti-

tuent cells of a vessel are merely separated by a kind of "grating" of bars.

Fig. 508.

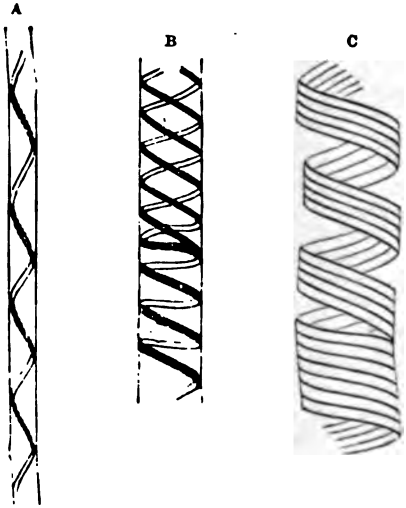


Fig. 508. A, B, C Spiral vessels from *Sambucus Ebulus*. Magn. 400 diam.

Fig. 509.

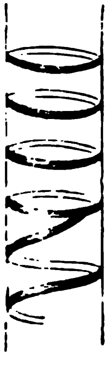


Fig. 510.

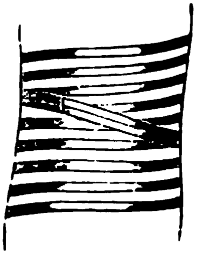


Fig. 511.

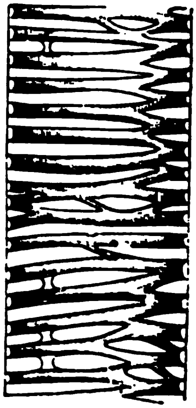


Fig. 509. Fragment of a vessel from the stem of a Gourd. Magn. 400 diam.
Fig. 510. Fragment of a spiral vessel of *Impatiens parviflora*. Magn. 400 diam.
Fig. 511. Fragment of the wall of a reticulated vessel of Rhubarb. Magn. 400 diam.

*Spiral vessels* (fig. 508) are found in the youngest and most delicate parts of the plants in which they occur. They are the parts of the woody structure first developed in stems; they are extensively developed in the ribs of leaf-stalks and leaves, and almost exclusively constitute those of the organs of flowers, as may be seen in petals. In stems and leaf-stalks, especially of fast-growing organs, the constituent cells are often very long and the course of the vessels straight; in roots, and in concentrated rhizomes and corms, &c., the constituent cells are mostly short and the course of vessels tortuous. The spiral fibre in the interior of these vessels has been considered to be hollow or tubular; but this is not generally regarded as correct.

*Annular vessels* (fig. 509) are found in situations similar to the last, being generally formed a little later in the same bundles. They are commonly of greater diameter than true spirals. This is the commonest form of vessel in the Equisetaceæ.

*Reticulated vessels* (fig. 511) are abundantly developed with the *spiral and annular kinds* in succulent stems, roots, petioles, &c. They are very important constituents in the fibro-vascular bundles of Monocotyledons generally. They are mostly of rather large diameter; their cells long in stem-structures, short and irregularly formed in roots and in the inner cortical region of Monocotyledonous stems, where a number of vessels are often anastomosed into a kind of network.

*Scalariform vessels* (fig. 491) are especially characteristic of the woody structures of the Ferns and Lycopodiaceæ, in which they sometimes occur of very large diameter.

Most vessels are cylindrical, and present a more or less circular section; but the scalariform are prismatic, usually with an hexagonal section.

Vessels, when once formed, are usually persistent; but in some water-plants the stem when young is traversed by a single spiral vessel, which disappears as the stem grows older, so that in the adult condition the stem seems wholly cellular with a central lacuna.

623. The *pitted* or *dotted ducts* (fig. 486) are characteristic of the wood of Dicotyledons, where they occur either scattered in the prosenchyma, or forming the principal constituent of the wood.

The walls of pitted ducts are not always uniform, this depending in some cases upon the nature of the organs with which they are in contact, whether cells or other ducts, since the pits always correspond on the walls of adjacent organs, and they are ordinarily less numerous and less regular on the walls of prosenchymatous cells than on those of ducts.

The pits and their borders (§ 584) are very generally somewhat elongated obliquely; and the canal of the pit is often enlarged into a transverse slit in the inner part, which in some cases becomes confluent with that of its neighbours. In some plants we find ducts with the wall marked both with pits and a spiral fibre, like the walls of the wood-cells of *Taxus* (fig. 492).

Pitted ducts with uniform walls make up the chief mass of the wood of *Clematis.* In the wood of Elder, Beech, Hazel, Alder, &c. we find ducts with pits numerous on the walls adjoining other ducts, but distant or absent on the walls adjoining wood-cells. In *Bombax* the wood-cells are for the most part replaced by parenchyma-cells, and the walls of ducts adjoining these have the pits destitute of the border &c.

Pitted ducts form the large tubes, visible to the naked eye, seen in cross sections of most woods, especially Oak, Mahogany, &c. They are absent from the wood of the Coniferæ, which is wholly composed of simple wood-cells (fig. 487).

624. *Vasa propria* are elongated cells with thin walls, and either oblique or flat ends where they adhere together; they vary in diameter, like the spiroids, and present on their walls large pits or spaces, covered with a kind of fine network of fibres, as in the clathrate cells described in a former section (§ 585).

Cells of this character (which differ from the conducting-cells before alluded to, in that the latter are destitute of markings or pits) always occur in the middle of the fibro-vascular bundles of Monocotyledons; and they are intermixed, mostly in alternate layers, with the liber in the fibrous layer of the bark of Dicotyledons. They are strikingly distinguished from *spiroids* by containing thick and opake sap, while the latter usually contain only air when fully developed.

Caspary includes under the head of conducting-cells not only those cylindrical tubes before alluded to, but also elongated cells having the form and appearance of vessels, except that they do not form continuous tubes, but are separated one from the other by partitions formed by the adjacent ends of the cells. The *laticiferous* ducts are mentioned elsewhere.

## *The Systems.*

625. The *Systems* are combinations of tissues, of like or different form and character, into elementary structures formed on definite plans, and destined for particular purposes in the economy of the plant.

626. In the simpler plants there generally exists no distinction of systems; but even in the higher Algæ and Lichens there is a difference in the cortical and medullary portions of the thallus. In plants possessing stems and leaves, the fibro-vascular or wood-system makes its appearance; and we may distinguish in the Phanerogamia three primary systems, viz. the *Cellular*, the *Fibro-vascular*, and *Cortical Systems*. These are all formed of proper constituent cells or tissues.

627. Besides these, we have systems which are formed for the most part by the interspaces between the cells of the above tissues, viz. the *Aërial System*, consisting of intercellular passages, spaces, or even large cavities; and the *Secretory System*, including the milk-vessels, reservoirs for secretion, glands, &c.

### A. *The Cellular System.*

628. This name is applied to the cellular tissues forming the great mass of the living structure of plants. In the Thallophytes it forms

the whole organization, the superficial layer of the larger kinds of thallus not being a true cortical layer like that of the higher plants. In the Mosses and Hepaticæ little is added to the cellular system, the *fibro-vascular* system appearing in a very simple form in the stems, and the *cortical* in the shape of an epidermis to the seta. In the higher Cryptogamia and the Phanerogamia the cellular system is less predominant, except in the temporary organs. In the stems and roots it forms the pith and medullary rays of Dicotyledons, and the diffused medullary system of Monocotyledons, together with the cambial structures in all growing regions; and it forms the mass of the leaves and the parts of the flower. It is in this system that the vital processes of vegetation are chiefly carried on.

### B. *The Fibro-vascular System.*

629. This system forms all the woody structures of plants, which in all cases are composed of a quantity of conjoined portions of cellular and vascular tissue arranged in a peculiar manner. The kind of cellular tissue associated with the vessels being mostly *prosenchyma* or *fibrous* tissue, the constituent elements of wood are called *fibro-vascular bundles.*

All woody substance appears originally in the condition of isolated fibro-vascular bundles, which, when they remain separate, form what are commonly called "fibres," and when they combine together into a solid mass, form "wood." The bundles remain as "fibres" in the stems of Monocotyledons; they are in the same state in the earliest conditions of the stems of Dicotyledons; and such "fibres" form the ribs of leaves and other organs.

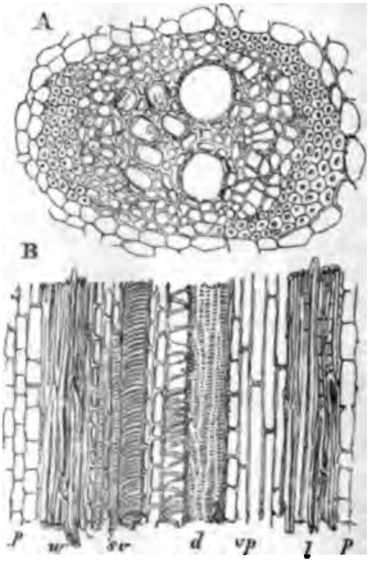
630. The fibro-vascular bundles differ in their modes of growth in different Classes of Plants, which, in consequence of this, exhibit considerable difference in the structure of their mature stems.

The simplest form is absolutely without the vessels, as we find it in the Mosses and some of the simple aquatic Phanerogamia (*Potamogeton*) composed simply of cords of prosenchyma traversing the cellular tissue.

631. Complete bundles, however, possess several elements arranged in definite order; these belong to the wood-region, the cambium-region, and the liber-region. The *wood*-region, which lies next the centre of the stem, is composed of short-celled prosenchyma intermingled with spiral and other vessels (and in Dicotyledons pitted ducts); the *cambium*-region is composed of prosenchyma in a nascent condition, the cells thin-walled, and retaining their primordial utricles; the *liber*-region is composed of very long prosenchymatous tissue (usually in the condition of isolated bundles or thin laminæ connected by cellular tissue in the

Dicotyledons). In the Monocotyledons the middle of the cambium-region is converted into *vasa propria* (fig. 512).

Fig. 512.



Monocotyledonous fibro-vascular bundle (from the spadix of *Phœnix dactylifera*). A. Transverse section. B. Vertical section: *p*, parenchyma in which the bundles lie; *w*, wood-cells; *sv*, spiral vessels; *d*, reticulated ducts; *vp*, *vasa propria*; *l*, liber-cells. Magn. 100 diam.

632. In the Higher Cryptogamia the bundles do not alter in their condition when once formed, and they anastomose with those that succeed them in successive internodes of the stem, so that the fibro-vascular structure appears *continuous*. In the Monocotyledons the bundles are formed by degrees, a cambium-region occupying the central part at first; but after a time this is wholly resolved into wood, liber, and *vasa propria*. These bundles remain isolated in the stem, never alter in condition after the first season of growth, and turn outwards to terminate at the surface of the stem above and below, anastomosing with their successors.

In the Dicotyledons the bundles in a young shoot somewhat resemble those of Monocotyledons, but they stand in a regular ring round the pith. On the inside they present spiral and annular vessels; next, a mass of prosenchyma with dotted ducts, which passes gradually into the cambium-layer; the latter is bounded externally by liber, among the bundles of which are *vasa propria*. These bundles are indefinite in their growth. The lower extremities elongate indefinitely in the root; the upper extremities anastomose and become continuous with their successors; and, above all, the cambium-region is an indefinite focus of development, forming a new layer of woody substance inside, and a new layer of liber outside during every season of growth.

The peculiarities of the fibro-vascular bundles will be better understood when we treat of the structure of *Stems*.

The different mode of growth of fibro-vascular bundles has given rise to a particular nomenclature for them. The bundles of Cryptogamia, developed in all parts at once, are called *simultaneous bundles*; those of

Phanerogamia, exhibiting when young a cambium-region, are *progressive bundles*, which, ceasing to develope at the end of the first season in Monocotyledons, are *definite*, but when growing season after season, as in Dicotyledons, are *indefinite*.

### C. *The Cortical System.*

633. In young stems and in herbaceous organs generally this system is termed the *epidermal system*; as stems grow older, this gives place to the *bark* or *rind*.

The simplest form in which the epidermal system can exist is that of a simple layer of flat cells firmly united by their sides, forming a continuous coat over the surface of a plant. The constituent cells of the epidermis are entirely devoid of chlorophyll or granular matter. Such an epidermis clothes all the organs of plants above the Class of Mosses; and it presents this simple general character on all young structures, with one special distinction only, that on submerged organs and on roots it is absolutely continuous and impervious; while on parts exposed to the air it presents more or less numerous orifices guarded by a peculiar cellular structure called a *stoma* (fig. 513, *a*).

634. The *stomata* are orifices between the meeting angles of the epidermal cells (fig. 514, B), in which orifices lie, rather to the underside, a pair of cells of semilunar form (fig. 514, A, C), separate on their adjacent sides, so that in expansion and contraction they close and open a slit-like passage beneath the superficial orifice. This slit (fig. 514, A, *s*) leads to an open intercellular space within the substance of the leaf.

In *Nerium* the stomata are on the walls of pits or depressions on the under face of the leaf. Sometimes the stoma is formed of four cells, and then either in two pairs, as in *Ficus elastica*, or the four cells form the quadrants of a circle, as in various Proteaceæ.

Stomata are most abundant usually on the lower surface of leaves, often wanting on the upper surface—except on the floating leaves of aquatic plants, where they exist on the upper surface, and are absent where the leaf touches the water. They are occasionally found in the interior of organs, as on the *replum* of Crucifers. They vary in frequency, partly bearing proportion to the size of the cells of the epidermis, partly irrelative to this. Sometimes 100 will be found in a square *line*, sometimes as many as 1000 to 3000. On the leaf of *Brassica Rapa* a square *line* bears 1800 on the upper face, 3500 on the lower; *Victoria regia* 1800 on a square line above, and none below. A few other examples may be cited.

| | On the upper face. | On the lower face. |
|---|---|---|
| Cherry-Laurel .............. | None. | 625 to a square line. |
| Laurustinus ................. | do. | 625 ” ” |
| *Daphne Mezereum* ............ | do. | 30 ” ” |
| Carnation ................... | 250 | 250 ” ” |
| Garden Flag ................. | 80 | 80 ” ” |
| Garden Rhubarb ............. | 7 | 30 ” ” |
| Lilac ....................... | None. | 1000 ” ” |

From the researches of Duchartre, Morren, and others, the following conclusions may be drawn, subject, however, to many exceptions. Stomata are more abundant in woody than in herbaceous plants, in leathery rather than in leaves of thinner texture. Succulent leaves contain the smallest numbers of stomata. Where leaves are alike in texture and colour on both surfaces, the number of stomata is about equal on both sides; when one side is glossy and the other dull, the stomata are most abundant on the latter &c.

Fig. 513.

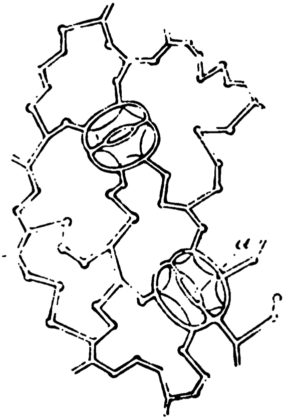


Fig. 514.

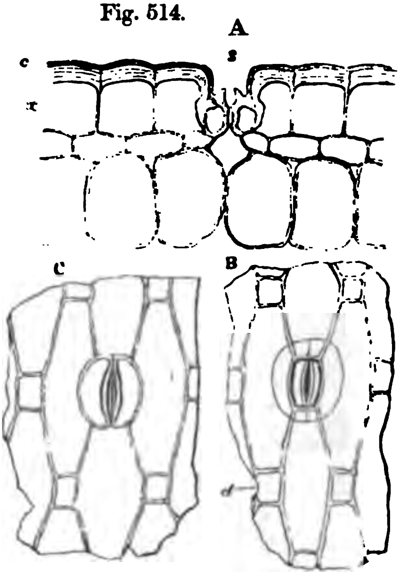


Fig. 513. Epidermis of the lower surface of the leaf of *Helleborus fœtidus*: *a*, stoma. Magn. 200 diam.

Fig. 514. Stomata of the leaf of *Narcissus Pseudo-Narcissus*. A. Vertical section of the epidermal and subjacent cells, passing through a stoma, *s*: *c*, cuticular pellicle extending down into the stomatal cavity. B & C. Horizontal section of the epidermis, passing through the plane of *x* in A: B, seen from above; C, seen from below; *d*, smaller epidermal cells corresponding in position to the stomata, but remaining in their original condition. Magn. 200 diam.

635. The cells of the epidermis exhibit a great variety of forms in the leaves and petals of Phanerogamia. It is very common for the side-walls, by which they adjoin, to be sinuous or zigzagged, often presenting very elegant patterns, especially on petals. The external wall of the cells is usually more or less convex; and in petals this condition is carried further, through numerous gradations, until we find a papillose condition, arising from each epidermal cell being produced above into a little obtuse cone.

636. Hairs and scales of all kinds, "scurf," such as we see in

the Bromeliaceæ &c., depend on the development of the epidermal cells. Simple hairs are merely single epidermal cells produced into a tubular filament; cell-multiplication usually occurs in such hairs, so that they present a number of joints (fig. 515, *b*); and not unfrequently they are more or less branched (fig. 515, *c*, *d*). Glandular hairs differ merely in certain of their cells secreting oils or resins in their cavities (fig. 515, *f*). Scales are produced by epidermal cells growing out into flat cellular plates instead of projecting filaments. Thorns, such as those of the Rose, the spines of leaves, like those of the Holly, &c. are epidermal products in which the cells become thickened by woody secondary deposits.

Fig. 515.

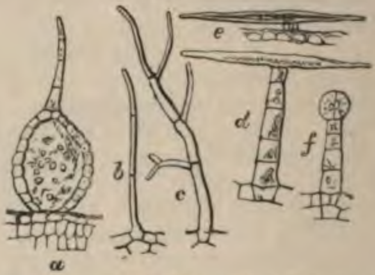


Fig. 515. Epidermal appendages: *a*, gland of *Fraxinella*, in vertical section; *b*, simple jointed hair of *Pelargonium*; *c*, hair of *Sisymbrium Sophia*; *d*, hair of garden Chrysanthemum; *e*, hair of a *Grevillea*; *f*, hair of the bulbil of *Achimenes*, with a glandular terminal cell. All magn. 50 diam.

637. The most remarkable diversities of condition of texture of herbaceous organs depend on the consistence which the epidermal layer acquires. The leathery texture of evergreens, the woody character of the leaves of Conifers, &c. depend chiefly on deposits formed on the wall of the epidermal cells.

In all epidermis exposed to the air, the outer walls of the cells become early strengthened by secondary deposits; these are very thin and slight in soft herbaceous leaves, especially when such

Fig. 516.

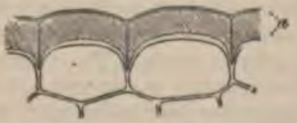


Fig. 517.

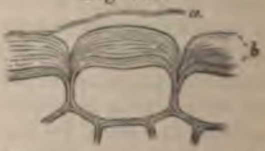
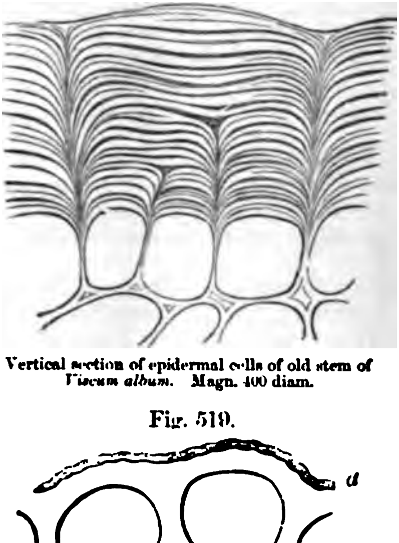


Fig. 516. Vertical section of epidermal cells of the leaf of *Hoya carnosa*: *a*, the portion of the secondary layer coloured yellow by iodine. Magn. 440 diam.
Fig. 517. Section as in fig. 516, treated with caustic potash: *a*, detached cuticular pellicle; *b*, the layers of thickening of the outer walls of the cells. Magn. 440 diam.

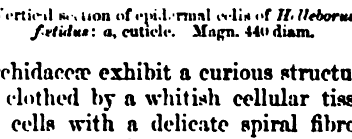
plants are reared in a warm, moist atmosphere. In leathery or hard leaves, also in the thick tough leaves of succulent plants, such as the Aloes, *Hoya* (figs. 516 & 517), &c., the secondary layers acquire great thickness; and in the epidermis of the branches of *Viscum* (fig. 518) the cells become absolutely filled up, and the cells of the subjacent layer of tissue also suffer the same change.

Fig. 518.



Vertical section of epidermal cells of old stem of *Viscum album*. Magn. 400 diam.

Fig. 519.



Vertical section of epidermal cells of *Helleborus fœtidus*: a, cuticle. Magn. 440 diam.

638. In the course of this thickening, the superficial laminæ, exposed to the air, become more or less chemically changed, and at the same time fused, as it were, into a continuous layer all over the surface of the organ; and by maceration or applying nitric acid we may separate this outer stratum as a continuous sheet or pellicle. This layer, which strongly resists decomposition, is called the *cuticle* (figs. 517 & 519, *a*). Some authors explain its origin by supposing it to be a substance excreted from the outer walls of the epidermal cells, and hardened into a pellicle (like a varnish) there. But by tracing the development, it is seen to be merely the altered outer walls of the cells.

In *Cycas*, the inner laminæ of the secondary deposits exhibit pits (§ 582) like those found on the walls of wood-cells: but this is a very rare phenomenon.

639. The aërial roots of Orchidaceæ exhibit a curious structure, the growing extremities being clothed by a whitish cellular tissue composed of several layers of cells with a delicate spiral fibrous deposit on their walls. This layer forms a kind of coat over the real epidermis of the root, and is known by the name of the *velamen radicum*.

640. *Cork*.—The young shoots of Dicotyledonous trees and shrubs are clothed with epidermis like herbaceous plants; but before the

close of the first season of growth, in most cases, the green colour gives place to brown, which is owing to the formation of a layer of cork from the outer layers of cortical parenchyma. Cork is composed of tabular thin-walled cells, containing only air; the surface of the corky layer is usually rough and irregular, and it peels off in laminæ periodically in certain plants, being renewed by development from the green cellular layer which it covers.

In some plants the corky layer is little developed, in others very much, as in the Cork-Oak. In the Vine and Clematis the corky layer is scarcely distinguishable after the first year's growth, as the bark breaks away, down to the liber, in stringy shreds. In *Viscum* no cork occurs; even in shoots eight or nine years old the epidermis remains, but completely consolidated by secondary deposits, as noticed above (§ 637).

### D. *The Aërial System.*

641. In most parenchymatous tissues of the higher plants we find the cells so disposed as to leave passages of greater or less capacity between them, which passages are usually found filled with air, apparently secreted from the contents of the cells. In imperfect parenchyma (fig. 470) these *intercellular passages* occupy a very considerable portion of the space filled by the tissue, and they intercommunicate in all directions. The spongiform cellular substance of leaves is traversed by larger passages of this kind (fig. 472), expanded in many places into *air-spaces*, forming a continuous system of cavities, which are in direct communication with the external air by the stomata. When stellate cellular tissue exists (fig. 474), the air-spaces are very extensively developed.

No intercellular passages or spaces exist in young tissues; they are subsequently formed by the cells separating from each other as they expand, and excreting air into the interspaces.

642. *Air-canals* are long tubular channels, in petioles (Nymphæaceæ) or stems (*Hippuris*, *Potamogeton*, &c.), bounded by a cellular wall, and generally arranged in a definite manner in the organs in which they occur. They are sometimes continuous through long tracts of the stems or petioles (Nymphæaceæ), or they are subdivided into chambers by cellular diaphragms occurring at intervals (petioles of *Musa*, stem of *Hippuris*, *Myriophyllum*, &c.).

643. *Lacunæ* are formed by this cellular tissue being torn down and destroyed by expansion of the surrounding tissue: examples of this occur in the fistular stems of Umbelliferæ, which when young have a solid pith; but this is torn away by the expansion of the cylinder of fibro-vascular bundles, and leaves a tubular cavity. The hollow stems of Grasses, of Equisetaceæ, &c. originate in the same way.

## E. *The Secretory System.*

644. The structures in which are found the substances usually called the secretions of plants, consist of *glands*, *reservoirs*, and *canals for peculiar secretions* (resins, oils, &c.), and the so-called *milk-vessels*. They for the most part occur only in particular plants or particular organs, and present many special modifications in different Natural Orders.

645. *Glands* are the structures of this kind most frequently met with, and they are generally connected in some manner with the epidermal tissue. Glands may be divided into *simple* and *compound*, and also into *external* and *internal*.

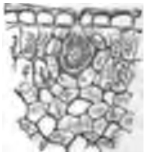
Simple external glands are in most cases glandular hairs; *i. e.* the terminal cell of a jointed hair is expanded and filled with oil or other secretion. Of this nature are the glands of the foliage, flowers, &c. of many Labiatæ, Scrophulariaceæ (fig. 515, *f*), &c.

Simple internal glands are mostly isolated cells of the layer immediately subjacent to the epidermis, as in the leaves of *Begonia*, *Lysimachia vulgaris*, the petals of *Magnolia*, &c. Such glands occur also in the leaves of Lauraceæ. The cystolithes of Urticaceæ are related to these (§ 612).

*Compound external glands* are sometimes hair-like growths from the epidermis, with the summit (*Drosera*) or the base (*Dictamnus*, fig. 515, *a*) developed into a cellular nodule, the cells of which either contain the secretion or surround a large central cell filled with it. Other superficial glands form papillæ of various shapes, in like manner either wholly formed of secreting cells, or with a central reservoir, as in the Hop, Begoniaceæ, Rosaceæ, Leguminosæ, &c.

*Compound internal glands* are commonly reservoirs surrounded by a special layer of cells, lying just beneath or sometimes rising in a dome-shape a little above the surface of the epidermis. Examples of this occur in the leaves of *Ruta* (fig. 520), the rind of the fruit of Oranges, Lemons, &c., leaves and stems of Hypericaceæ, Myrtaceæ, &c.

Fig. 520.



Vertical section of epidermis and subjacent gland of *Ruta graveolens*. Magn. 50 diam.

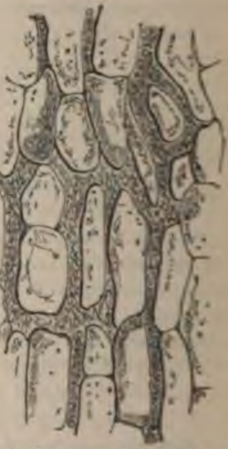
None of these glands have excretory ducts like the glands of animals. In many cases the secretions exude through the membrane, and give a peculiar character to the surface of the organs in which they are found. A very general form of secretion of this kind is the exudation of saccharine fluid from the superficial cells, very common at the base of petals and ovaries, on the stigma, and sometimes on leaves, or at particular points of the lower surface of the leaves, as of *Prunus Laurocerasus*, the Laurustinus, and other shrubs.

646. *Stings* are a form of glands, consisting of a long, stiff and

pointed hair expanded into a bulb at the base, containing the poison. This bulb is surrounded by a layer of cells derived from the epidermis, which by their tension exert a certain pressure, whence it results that when the point of the stinging-hair is broken off, the fluid is pressed out from the orifice.

647. *Reservoirs for peculiar secretions* may be regarded as a highly developed form of the internal glands. Those of the Coniferæ consist of cylindrical bundles of thin-walled cells, filled with resin, lying in the midst of the wood, parallel with the fibro-vascular structures. Similar reservoirs exist in the roots of Rhubarb, in the leaves of *Aloes*, &c.

Fig. 521.



Laticiferous canals from the root of Dandelion. Magn. 100 diam.

648. The *canals for secretions* differ from the foregoing in being intercellular channels bounded by a definite layer of cells conjoined so as to form a closed tube. Such canals occur, containing resin, in the bark of the Coniferæ, in the petioles of Cycadaceæ, in the Umbelliferæ, Compositæ, Anacardiaceæ, &c. &c.

649. The *milk-vessels* or *laticiferous canals*, containing the *latex* or milky juice of Papaveraceæ, Euphorbiaceæ, Cichoraceæ, &c., appear to be intercellular passages which become bounded by a false membrane from alteration of the walls of the cells between which they lie; and this view of their structure has till recently been the one most generally adopted; but the more recent researches of German and French anatomists lead to the conclusion that they are formed, like other vessels, from the confluence of cells into tubes. Trécul even states that the laticiferous tubes anastomose with the true vessels and pass their contents into the cavity of the latter. They occur most abundantly in the pith and inner layer of the bark of stems, and in the cellular substance of roots, and are found in the form of more or less regular, simple or ramified channels in stems, petioles, &c., but much more irregular and tortuous in roots, and frequently anastomosed into a complete network. Examples of the former may be found in stems of Papaveraceæ, *Ficus elastica*, &c.; of the latter in the roots of the Dandelion (fig. 521), Chicory, &c. Dippel, who made a special study of these organs, holds that the laticiferous vessels replace the "clathrate cells" of other plants.

The milk-vessels contain an opalescent granular fluid, in which are suspended globules of caoutchouc or other resins, and frequently also starch-granules. The milky character is only acquired on exposure to the air, and it disappears again as the juice hardens into a resin.

Latex-canals are remarkable among the secreting-apparatus of plants, from their juices containing many of the most active and important of the special organic compounds. Besides the pure gum-resins, such as Caoutchouc, Gutta-percha, Gamboge, &c., they carry substances containing vegetable alkaloids, such as Opium, Lactucarium, &c.

## **Sect. 4.** INTERNAL ANATOMY OF ORGANS.

650. All young plants are composed of cellular tissue alone; and the Thallophytes never acquire any of the more highly developed "systems" which we meet with in full-grown flowering plants and the higher Cryptogamia. In the stems of the latter, the "systems" present special modes of arrangement, respectively characteristic of the great Classes.

The more or less uniform condition of the tissues in the Thallophytes is connected with great simplicity in the physiological processes of vegetation and growth; while in the higher plants the difference of internal organization is accompanied by important differences in the modes of development of the axis. It would cause us to exceed our limits very widely to enter into minute details of the internal structure of the organs of vegetation of plants generally; but it is requisite not only to give a general sketch of the plan of organization, but to describe some of the more important modifications met with in the higher Classes.

### *Structure of Stems &c.*

651. As a general rule, plants possessing stems and leaves exhibit in their *stems* a definitely arranged fibro-vascular system, the bundles of which send off branches, or pass off themselves entirely, to form the ribs and veins of the *leaves*. The same axial system furnishes below, directly or indirectly, the bundles which constitute the woody central mass of *roots*.

Exceptions to the above occur in the highest Classes, in plants with vegetative organs of low type and in aquatic plants; in the latter especially, the fibro-vascular bundles seldom extend into the blade of the leaf.

652. The simplest form of the fibro-vascular system is seen in the Mosses (p. 421), where a cord of prosenchymatous tissue runs up the centre of the thread-like stem, and in some cases sends off branches to the leaves.

653. In the Lycopodiaceæ (p. 412) the axis of the stem is occupied by a fibro-vascular bundle containing spiral and scalariform vessels, which is regularly developed onwards with the growth of the point of the stem, sending off lateral branches of spiral vessels where leaves

arise, but undergoing no change after the internode in which it lies is once formed.

654. In the Equisetaceæ (p. 414) a ring of isolated fibro-vascular bundles exists in the periphery of the aërial stem, surrounded by liber-cells and parenchyma; these, again, are simultaneous bundles (§ 632), and grow only at their points as the stem elongates. The constituent vessels are spiral or annular.

655. In the Ferns (p. 416), where the stem acquires greater dimensions, we find a number of fibro-vascular bundles standing in an irregular circle, surrounding a central cellular axis, and externally surrounded by a kind of rind. The bundles do not run straight up the stem, but in waved curves; and they anastomose laterally and separate again, leaving wide passages of communication between the central parenchyma and the rind (fig. 522). The branches of the bundles going to supply the leaves are given off at the anastomoses of the main bundles; and the bundles running into the (adventitious) roots arise at similar places. These bundles are "simultaneous;" and therefore the stems never alter in dimensions when once formed.

In cases like that of *Angiopteris evecta*, where the stem is reduced to very small proportions, there are, according to Mettenius, three zones of fibro-vascular bundles, one within the other, and connected by intervening net-like bundles. It was formerly supposed that vessels of the scalariform type were the only ones that occurred in Ferns; but it is now well known that spiral and annular vessels also occur especially in the younger portions.

656. All the above forms of the stem are characterized by being developed only at the point, and containing only such bundles as are unlimited in growth at their apex, but have their elements developed simultaneously, and "completed," as it were, in each internode, step by step, with the elongation of the stem.

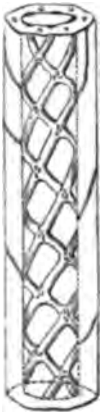
From this circumstance, these higher Cryptogamia are often called *Acrogens*, or *Acrobrya* (point-growers). (See pages 192 and 193.)

657. The stems of Monocotyledonous plants (§ 30) have a very different organization from the above. The most striking peculiarity, at first sight, is the isolation of the fibro-vascular bundles, which, as a rule, do not anastomose in any part of their course through the stem, and are scattered singly in the parenchyma of the stem (fig. 523). Another important circumstance is, that they pass entirely into the leaves at their upper ends (fig. 524, *a*), while at their lower extremities they approach the surface of the stem and anastomose with their fellows to form a more or less developed fibrous network, separating the rind or cortical parenchyma from the central fibrous part of the stem. It is from this network that the fibro-vascular axes of the (adventitious) roots are derived (fig. 524, *b*).

658. The stems of Monocotyledons are very generally herbaceous, and thus present very important varieties of form, arising from non-development of internodes, according to regular plans. These modifications disguise the structure; but it may be readily understood by means of diagrammatic illustrations of some of the principal forms

Fig. 524.

Fig. 522.



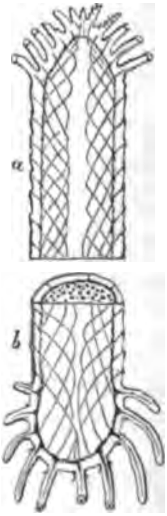


Fig. 523.

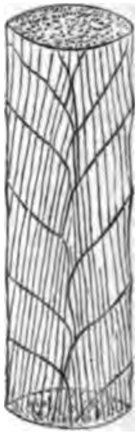


Fig. 522. Diagram of the arrangement of the fibro-vascular bundles in the stem of a Tree-fern.

Fig. 523. Diagram representing the arrangement of the fibro-vascular bundles in a Palm-stem.

Fig. 524. Another diagram, representing the upper (*a*) and lower (*b*) extremities of a Monocotyledonous trunk, with its fibrous layer where the stem-bundles terminate and those of the root commence, enclosed by a cortical layer.

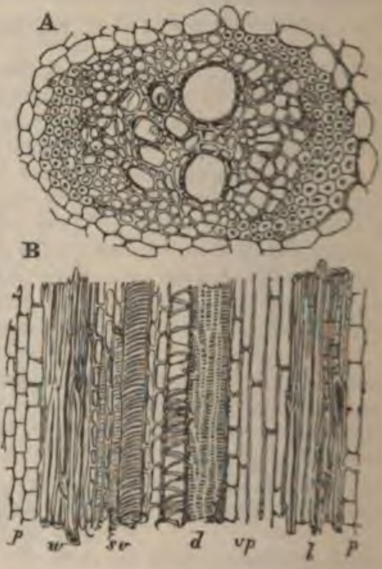
659. The fibro-vascular bundles of Monocotyledons (fig. 525) being of the *definite* (§ 632) kind, they acquire their full development in each internode before the leaves to which they belong fall; and hence the stems of this class do not increase in diameter as a general rule, but have a columnar character when they form woody trunks. But there are exceptions to this rule.

660. It has just been stated that the fibro-vascular bundles terminate below, near the periphery of the stem, and there form a more or less evident network of fibres; this network constitutes a kind of sheath round the general mass of the stem, and is itself covered by a more or less developed *rind* or cortical parenchyma (fig. 524, *b*). The tissue in the region of the fibro-vascular network, or *fibrous layer*,

remains in most cases in the condition of cambium, as we see adventitious roots readily formed in this situation. In *Dracæna*, *Yucca*, and some other woody Monocotyledons, the stem becomes increased in thickness with the age of the tree, by the formation of layers of liber-like prosenchyma in this *fibrous layer* pushing the rind outward. The original central fibro-vascular system of the stem remains unaltered.

661. The region, at the junction of the central and cortical parenchymas, where the fibro-vascular bundles terminate, should perhaps be called a *cambium*-region, since the cellular tissue situated here retains its developmental power in many cases. The essential difference between this and the cambium-ring of Dicotyledons depends on the fact of its not coinciding, in a parallel arrangement, with the cambium-region of the fibro-vascular bundles, but with the *extremities* of the bundles, which always remain isolated from each other. The successive layers of fibrous structure in *Dracæna* &c. are formed in like manner of isolated bundles, imbedded in parenchyma; they are unconnected with the old bundles of the primary axis, but are continuous above with the *lower ends* of bundles belonging to the *branches* occurring in these stems.

Fig. 525.



Monocotyledonous fibro-vascular bundle (from the spadix of *Phœnix dactylifera*). A. Transverse section. B. Vertical section; *p*, parenchyma, in which the bundles lie; *w*, wood-cells; *s v*, spiral vessels; *d*, reticulated ducts; *v p*, *vasa propria*; *l*, liber-cells. Magn. 100 diam.

662. The stems of herbaceous Monocotyledons have the fibro-vascular system always in the form of "stringy" fibres imbedded in succulent parenchyma; and in those perennial stems of the Class which acquire a solid woody structure the ligneous character depends, not on the fibro-vascular system, but on the general parenchyma of the stem having its cells lignified, of which we have examples in the Cocoa-nut and other Palms, in the Bamboo, &c.

663. The *rind* of the Monocotyledonous stem, totally different

from true *bark*, is generally little developed. On herbaceous stems it is a mere epidermis; but on fleshy rhizomes it sometimes acquires considerable thickness, and is then found to be composed of spongiform parenchyma, with large air-cavities, the whole bounded externally by a few layers of tubular parenchyma with a corky outer surface.

A certain number of forms occur aberrant from the type above described. In *Aloe* the fibro-vascular bundles are so arranged as to form a kind of cylinder, separating a central from a cortical parenchyma. In the Smilaceæ, Dioscoreaceæ, and some other Orders the rhizomes imitate still more the Dicotyledonous arrangement; for not only do the bundles stand in circles, they do not pass wholly off into the leaves, but run continuously through the structure. Still there is no periodical resumption of activity in the bundles, as in the Dicotyledons. In *Tradescantia*, and in the Grasses also, anastomoses of the isolated fibres take place at the nodes of the stem.

664. The stems of Dicotyledons, and of Coniferæ which agree in the main points, are at first of very simple structure, almost resembling those of the Ferns; but their fibro-vascular bundles being of the *indefinite* kind, capable of lateral growth by addition of new elements season after season in their outer regions, the full-grown stems depart widely from the preceding types.

For purposes of comparison, attention must be confined to shoots or stems of Dicotyledons in their first year of growth, as the formation of annual layers is a phenomenon to which there is nothing correspondent in the other Classes (excepting Conifers).

Fig. 526.

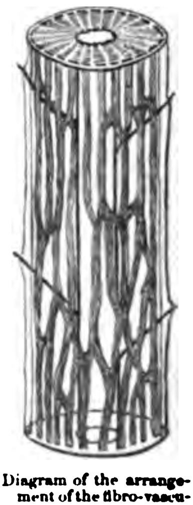


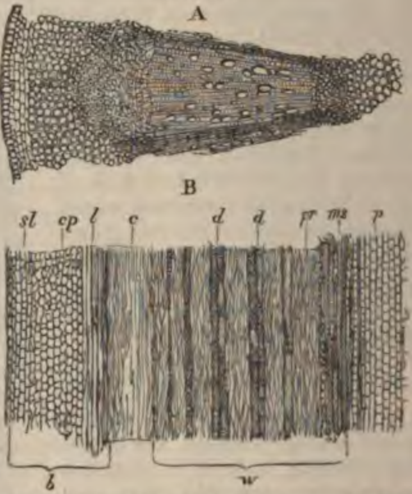
**Diagram of the arrangement of the fibro-vascular bundles in a yearling stem of a Dicotyledon.**

665. When a young herbaceous stem of a Dicotyledon is cut across, we find the fibro-vascular bundles standing in a circle around a central parenchymatous mass, the pith, and enveloped by a cellular rind (fig. 526). The bundles run in tolerably straight vertical courses, and anastomose freely; a certain number of bundles belong to each leaf; but they do not pass off into the leaves, merely sending a branch from the inner vascular part of the bundle, while the outer woody mass is prolonged upwards, and is uninterruptedly continuous with a new bundle belonging to the leaf directly above it (which, as follows from the laws of Phyllotaxy (§ 60 *et seqq.*), is generally at a distance of several internodes).

666. As the stem increases in age, each fibro-vascular bundle forms a wedge-shaped mass of wood (fig. 527) by development of the inner part of the cambium-region, and at the same time a layer of liber

at the extreme outer side, next the bark. At the close of the first season, therefore, we have a central *pith* (fig. 527, *p*), immediately bounded by the vascular portion of the bundles (called the *medullary sheath*) (*m s*), from which pass the branches to supply the leaves with ribs; next come the wedges of *wood* (*w*), formed of prosenchyma (*pr*) and ducts (*d*, *d*) in most Dicotyledons, of prosenchyma alone in Conifers, which passes into the *cambial* or reproductive layer (*c*); and this is continuous outside with the *liber*-bundles (*l*), corresponding to the wedges of wood; the liber-fibres, like the inner vascular elements, send branches to form part of the ribs of the leaves.

Fig. 527.



Dicotyledonous fibro-vascular bundle (Plane-tree) of one year's growth. A. Transverse section. B. Vertical section; *sl*, suberous layer of the bark; *cp*, cortical parenchyma; *l*, liber; *c*, cambium-region; *d*, ducts lying in the prosenchyma, or wood-cells, *pr*; *ms*, medullary sheath of spiral vessels; *p*, pith. The structures connected by *b* belong to the bark, those marked *w* to the wood. In A, the bundle is seen to be bounded on each side by a medullary ray, running from the pith to the cortical parenchyma. Magn. 50 diam.

667. The fibro-vascular bundles, standing side by side, do not become absolutely united, but are separated by thin plates of compressed cellular tissue, running out from the pith to the cortical parenchyma; these plates are called *medullary rays* (fig. 528).

668. The liber-portions of the bundles are associated with rows of clathrate cells (§ 585), and frequently with latex-canals, and they are surrounded by a layer of parenchyma, composed of cells filled with sap and containing chlorophyll, the *cellular envelope* (fig. 527, *c p*); and this is protected externally by the dry *suberous layer*

(*s l*), which succeeds to the epidermis when the herbaceous shoot acquires a woody character.

Many special modifications of the above type are met with in Dicotyledons. In the Piperaceæ there is a kind of double concentric circle of fibro-vascular bundles, the inner circle supplying the leaves, but not possessed of a cambium-region; while the outer circle is of the ordinary *unlimited* character. In the Sapindaceæ, Malpighiaceæ, and some other Orders, part of the fibro-vascular bundles remain separate from the principal circle, and lay the foundation of a number of secondary cylinders of wood, enclosed by a common bark; this phenomenon may be well observed in *Calycanthus*, where a square form of the stem results from four fibro-vascular bundles remaining free from the central cylinder of wood in this way.

In the Nymphæaceæ we find a very aberrant condition: the fibro-vascular bundles, formed of vessels and parenchymatous cells alone, without wood, are quite isolated, destitute of *cambium*, and form a complicated interlacement closely resembling that occurring in Monocotyledons—there being no distinction of pith and medullary rays, and no bark.

A still more frequent source of diversity lies in the varied nature and mode of arrangement of the elements of the *wood*. In the Plane (fig. 527) we see the spiral and annular vessels succeeded by a body of prosenchyma, in which are scattered large pitted ducts. In the Hazel and Alder these ducts are far more numerous, as they are also in the Lime. In the Oak the prosenchymatous cells are very small, and become greatly thickened, but the ducts are large. The Box has very small and dense prosenchyma-cells and few and small ducts. In the spongy wood of the Bombaceæ the prosenchyma is almost wholly replaced by thin-walled parenchyma.

In the Coniferæ there is a total absence of ducts, the wood being formed exclusively of prosenchyma with the peculiar *bordered pits* (fig. 487), or, as in *Taxus*, with both pits and a spiral fibre (fig. 492).

669. With the commencement of a second season of growth, a Dicotyledonous stem begins to acquire its especial peculiarities. When the buds open to produce new shoots, cell-division recommences in the cambium-region of the old bundles, and an additional layer of wood is added gradually during the season to that formed the year before. Season after season this process is repeated, and thus the cross sections of the stems present a series of concentric laminæ of wood corresponding to the number of seasons during which the stem has existed (figs. 528 & 529).

The concentric lamellæ of wood in Dicotyledons are really *annual rings* in most trees of temperate climates. In the tropical trees it frequently happens that more than one ring is formed annually. In our own trees an interruption to the vegetation, such as is caused by an accidental *defoliation* during the summer, produces additional annular markings. In the common Beet-root several rings are produced in one season.

In some tropical trees (Malpighiaceæ) the concentric circles are not very clearly marked; in others they are even separated by a distinct layer of parenchyma. In the Bignoniaceæ it is common to find the wood divided into four large portions, separated by wedge-shaped cortical structures, giving in the horizontal section the form of a cross. The old stems of such plants as the Sapindaceæ &c., above referred to, with isolated bundles outside the central woody cylinder, acquire very anomalous forms with age, since each collection of fibro-vascular bundles is developed annually in its cambium-region, and hence the stem assumes the appearance of several stems enclosed in a common bark. In Cycads more than one year is required to complete a woody zone; thus, in very old stems of Cycads, only a few rings are seen surrounding a voluminous pith.

Fig. 528.

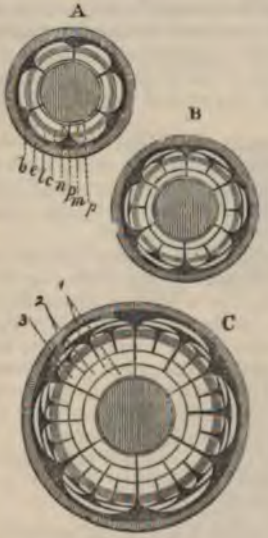


Fig. 529.

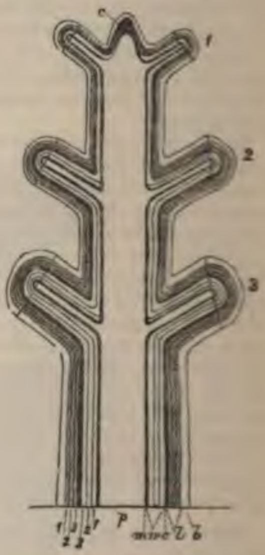


Fig. 528. Diagrams of cross sections of a one-year (A), two-year (B), and three-year old (C) Dicotyledonous stem, or of the branches 1, 2, and 3 of fig. 529. The letters to A indicate:—*b*, suberous layer; *e*, cellular envelope running in to the black medullary rays; *l*, liber; *c*, cambium-region; *n*, wood; *p*, medullary rays; *m*, medullary sheath of spiral vessels; *p*, pith. The figures to C, 1, 2, 3, mark the wood and liber belonging to the 1st, 2nd, and 3rd year.

Fig. 529. Diagram of a vertical section of a Dicotyledonous stem 3 years old, with 3 branches marked 1, 2, 3, indicating the age in years of the branch and the internode below it. The figures below denote the ages of the layers of liber and wood; *p*, pith; *c*, cambium; *m*, medullary sheath; *w c*, layers of wood; *l*, layers of liber; *b*, cellular and corky layer of bark.

670. As woody trunks increase in size, the older parts of the wood frequently go on increasing in density by the formation of secondary layers in the cells of the prosenchyma; thus the old central wood becomes more solid, forming what is called the *duramen*

or *heart-wood*, which is sometimes deeply coloured by chemical changes or secretions of various substances, as we see in Ebony, Lignum Vitæ, &c. The young external layers of wood, in which the ascending current of fluid passes freely, is called the *alburnum* or *sap-wood*.

671. The fibro-vascular systems of the branches of Dicotyledons originate independently in the bud, but soon become blended with those of the parent axis, with which their layers of increase become uninterruptedly continuous. When a branch is broken off short, leaving no buds upon it to continue its growth, it becomes surrounded and ultimately entirely enveloped by the succeeding annual layers of wood, and in this way forms a "knot." The numerous small knots of the wood of *Pinus sylvestris* arise from certain of its branches being broken off while small.

672. The *pith* or *medulla* consists of parenchymatous tissue, filled with nutrient matters, stored up for the use of the growing tissues. It is of most service in young twigs, and becomes inert in after-life, and often disappears as the wood grows. It exists either as a continuous cylinder, or is broken up into disks separated by cavities one from the other as in the Walnut. In some cases some of the cells of the pith retain their vitality longer than others, so that there is an admixture of living and dead cells; and in this way the differences in the pith may even serve to distinguish certain genera one from the other.

673. The *medullary rays* (fig. 528, A) which separate the primary bundles are developed in the cambium-region with the yearly layers of wood, and always extend to the cortical parenchyma; in the layers of successive years the new elements of the wood separate into parcels divided by *secondary medullary rays* (fig. 528, B, C), which are repeated in each successive season. The course of the fibro-vascular bundles being slightly sinuous, from their lateral anastomoses, the medullary rays have, singly, no great vertical dimensions; and their transverse diameter varies in different cases. Their cells become lignified in heart-wood.

674. The *liber* is usually formed in successive thin laminæ composed of slender laterally anastomosing bundles of liber-cells; and in some plants these laminæ are separated by layers of parenchyma, so that the liber-structure of old stems may be split into its annual layers. In some stems the liber ceases to grow after the first season.

The *bast* of which Russia matting is made consists of the separate liber-layers of the Lime-tree. The "lace" of the Lace-bark tree (*Lagetta lintearia*) is the liber, and that of other trees of the Order Thymelaceæ is used for tying up bundles of cigars &c.

675. The *cellular envelope* (fig. 527, *cp.*) is generally in an active condition of vegetation during the growing-season, since its tissue

must increase laterally (tangentially to the stem) to allow of the increasing diameter, while it produces the new suberous structure on the outside.

676. The *suberous layer* differs much in its condition in different trees. When it is composed of a few layers of tabular cells slowly increased within as the surface splits and decays, it forms a mere *periderm*: in some trees this is formed of alternate layers of large-celled and small-celled tissue, and splits and curls up into rolls, which gradually fall away (Birch). In other cases it is thrown off periodically in large plates by expansion of the subjacent green cellular layer which reproduces it (*Platanus*). In the Elm, Oak, &c. the corky layer is developed regularly internally, and does not separate; it hence acquires considerable thickness, and is irregularly split up by the expansion of the stem, thus forming a rugged rind.

In the Cork-Oak the suberous layer is greatly developed, receiving considerable increment every year, composed of thin-walled muriform parenchyma.

In the Vine the old liber is thrown off annually with the scarcely distinguishable periderm; and the same takes place in *Clematis*.

### *Structure of Roots.*

677. The anatomy of roots presents important modifications; but these are less striking than those met with in stems. It is necessary to restrict our account of these organs to the principal facts only. In all cases they have a fibro-vascular axis enveloped in a more or less thick cortical parenchyma, covered when young by a delicate epidermis devoid of stomata (sometimes called *epiblema*), when old by an epidermal tissue of corky nature.

678. The roots of the Vascular Cryptogamia (Ferns, Lycopodiaceæ, &c.) are all adventitious, and, excepting in the comparatively few arborescent forms, are soft, succulent filaments dying off after a certain time, to be replaced by new ones formed higher up on the stem. Their structure consists merely of a central fibro-vascular axis, surrounded by a cellular cortex and an epidermis provided with numerous root-hairs of a yellowish colour.

679. Dicotyledons produce an axial (§ 35) root, which is a direct prolongation of the stem downwards; and both this and the adventitious roots frequently developed on the stem have the peculiar unlimited fibro-vascular structure found in the stems of this Class, and may become woody and increase by annual layers like the ascending axis.

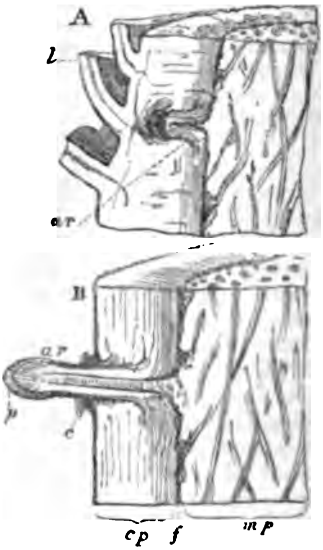
680. The radicle of a Monocotyledonous embryo is never developed; but if we make a section of the lower part of the embryo, we find one or more little conical bodies imbedded in the parenchyma; these are the nascent adventitious roots, which soon appear exter-

nally by breaking their way mechanically through the superficial tissue. The anatomy may, however, be more easily studied by tracing the development of the adventitious roots on the rhizomes of Rushes, Flags, and other plants of this Class. The roots originate (fig. 530, A, *a r*) in the region where the fibro-vascular bundles of the stem terminate (and frequently form a fibrous plexus (§ 657)). They are at first wholly cellular, and we may distinguish in them three parts,—a woody axis, which soon becomes continuous with the fibro-vascular plexus; a cortical parenchyma, continuous with the *inner* part of that of the parent stem; and a kind of conical hood of rather dense cellular tissue, enveloping the end of the root. As the root grows, it pushes the hood forward, which breaks down the cellular tissue before it, and finally appears externally. When the epidermis is ruptured in this way, it presents a circular free edge standing up slightly like a collar around the base of the free part of the root: this is called the *coleorhiza* (fig. 530, B, *c*) by some authors. The conical hood upon the apex of the root, called the *pileorhiza* (fig. 530, B, *p*), is more or less persistent in different cases; in aquatic plants it becomes greatly developed, as may be seen in the Duckweed (*Lemna*), where it forms a long sheath, appearing as if slipped over the end of the rootlet. The focus of development of the root is within the *pileorhiza*, which is pushed forward by the continual development of cells just behind the apex.

The *pileorhiza* may be compared to a kind of shield or guard to the tip of the root, protecting the nascent tissue, by the expansion of which it is pushed forward, itself always possessing a certain solidity which enables it to penetrate between the particles of the soil.

681. In a cross section of the root of a Monocotyledon we see the centre occupied by prosenchymatous tissue, with a circle of vessels around it: the whole enclosed by regular parenchyma, sometimes by

Fig. 530.



Development of adventitious roots in *Sparganium*. A, B. Fragments of a rhizome with cortical parenchyma (*c p*), fibrous layer (*f*) where the fibro-vascular bundles terminate, and central region (*m p*) in which the bundles run. A, *a r*, shows an adventitious root arising from the cambium tissue at the outside of the fibrous layer; in B the more advanced root (*a r*) has emerged, leaving a ragged collar or coleorhiza (*c*), and having a root-hood or pileorhiza on its extremity.

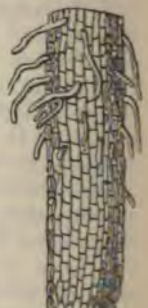
liber-cells and covered by an epidermis. The ring of vessels spreads out into a kind of rosette at the base, and anastomoses with the extremities of the fibro-vascular bundles of the stem in the fibrous region (fig. 530, *f*). Secondary adventitious roots are formed in the same way in the roots, originating immediately upon the vascular ring and breaking through the cortical parenchyma.

The woody adventitious roots of arborescent Monocotyledons differ only in the greater development of the fibro-vascular structures; and they emerge from the stem (Palms) in the form of thick conical shoots.

682. When adventitious roots, like those just described, die away, they decay down to their very origin, and leave a scar in the form of an orifice surrounded by the ragged coleorhiza.

In the thickened adventitious roots of *Asparagus*, which perform the function of *tubers*, the parenchyma is greatly developed. In the tuberous roots of Orchids (figs. 20 & 21) the central woody axis becomes irregularly expanded into parenchymatous tissue driving the vessels out nearly to the periphery, so that the characteristic structure is greatly disguised. The aërial roots of the epiphytic Orchids have the growing extremities clothed by several layers of a parenchymatous tissue, in which the cells are characterized by delicate open spiral-fibrous secondary layers.

Fig. 531.



Extremity of the root of a germinating Turnip. Magn. 30 diam.

683. The axial root of Dicotyledons, being a direct continuation of the stem, displays a circular group of fibro-vascular bundles as in the ascending axis; but these mostly converge at the point of junction of stem and root (*collar*), so that the central axis of parenchyma, the *pith*, is usually absent, the medullary rays (§ 667) remaining as in the stem. Externally, again, there is a difference, since the liber-bundles vanish and the cambium-region passes at once into the cortical parenchyma, here colourless and succulent, and this is clothed by a less prominent *periderm* than the stem. The roots of Dicotyledons increase in diameter by annual layers of wood formed in the fibro-vascular bundles, these, however, being much less regular in their arrangement than those of the stem on account of the tortuous course of the roots; hence while the wood of the roots is often useful for ornamental purposes, it is comparatively valueless for carpenters' uses. The branches of the axial root are originally growths from the apex of the root, thrown off to the side, as it were, and their woody axis is derived from a division of that of the main root.

The radicle of a germinating Dicotyledon has its *pileorhiza* (fig. 531), and grows, in the same way as that of the Monocotyledons, by development of cells just behind the apex. Young roots are covered by a delicate epidermis; and the cells of this are abundantly produced into hairs (*fibrillæ*) in many plants, especially in those growing in light soils; these fibrils are deciduous, the delicate epidermis (which is always destitute of stomata) being gradually converted into a corky layer.

Adventitious roots are very common in Dicotyledons, especially the herbaceous perennial kinds, and they alone can exist on plants raised from *cuttings* &c. of stems. The roots originate much in the same way as those of the Monocotyledons, appearing first as cellular cones in the region adjacent to the cambium-layer, with which the fibro-vascular structure soon becomes confluent. They break through the rind, with a coleorhiza, and protected by a pileorhiza, just as in Monocotyledons; but when once formed, they appear to branch in the same manner as the axial root, and not by the formation of secondary adventitious roots.

Trécul states that the structure of adventitious roots differs according to the part of the stem whence they emerge. If, for instance, they originate opposite a fibro-vascular bundle, as in *Nuphar*, the centre of the root is occupied by a bundle of fibro-vascular tissue; if they spring from the stem opposite the pith or cellular tissue between the vessels, then the centre of the root is likewise cellular. In Cryptogams, according to Nägeli, the roots always originate opposite a fibro-vascular bundle. The primary form and disposition of the roots depend in a measure on the form of the terminal cells and on the direction of the partitions by which it is divided—lengthwise, horizontal, or oblique.

Tuberous roots of herbaceous Dicotyledons present several modifications in the arrangement of the structures. In the Carrot and Parsnip the fibro-vascular ring has its component parts much separated by the great development of the medullary rays and masses of parenchyma replacing the ordinary prosenchyma of woody roots, so that the fibro-vascular structure has a deceptive resemblance to that of Monocotyledons; and the cortical parenchyma, again, is greatly developed, so as to form a thick fleshy rind. In the Turnip the cortical parenchyma is little developed, and the mass of the fibro-vascular bundles lies immediately under the rind, the inner vascular parts of the bundles being split up, as it were, into a row of fibres radially arranged and imbedded in a great quantity of lax parenchyma. The fibro-vascular bundles converge at the "collar," and then separate again to surround the *pith* of the stem; they also converge again towards the point of the root. These so-called roots are more nearly allied to the stem, and are, indeed, hypocotyledonary stems.

The structure described under the name of *spongioles* has no existence in nature. The error has probably arisen from the appearance presented by the *pileorhiza*.

Roots grow by cell-development only near the apex; and interstitial expansion soon ceases. Old roots of Dicotyledons present a dense heart-wood like the trunks, the passage of fluid taking place through the outer layers. When the older parts of roots are exposed to the air by removal of soil, they acquire a thick corky *periderm.*

The general structure of the root of Conifers is like that of Dicotyledons.

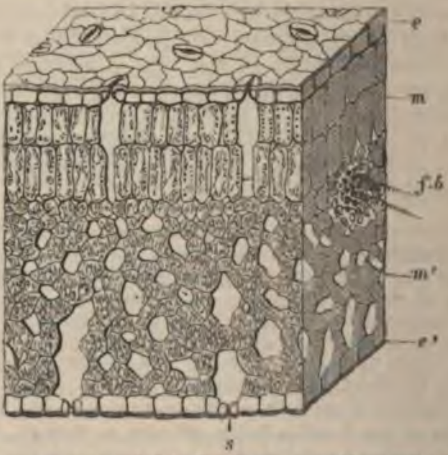
### *Structure of Leaves &c.*

684. The plan of construction of the leaves and of the other appendicular organs of the stem is in the main identical throughout all cases; but there is very considerable variation within the limits of the general type.

685. The essential character of the anatomy of a leaf is, that it is an expanded layer of parenchyma clothed over its whole surface with epidermis, and furnished, according to its degree of development, with a more or less extensive and complicated framework of fibro-vascular bundles.

In the leaf of the Turnip, for example (fig. 532), we find an upper (*e*) and lower (*e'*) epidermis (§ 633), with an intermediate mass of parenchyma (or merenchyma, *m*, *m'*), rather close in the upper part, and spongiform in the lower part. The epidermis is studded with stomata (*s*), which open into intercellular spaces communicating freely throughout the spongy tissue, and, further, through the petiole, with the intercellular passages in the stem. The fibro-vas-

Fig. 532.



Projection of a fragment of the leaf of the Turnip, constructed from sections made in various directions, and magn. 100 diam.: *e*, epidermis of the upper surface with its stomata; *e'*, epidermis of the lower face; *s*, stomata, cut through, opening into intercellular cavities; *m*, close parenchyma of the upper part of the leaf; *m'*, loose and spongy parenchyma of the lower part; *f.b*, the cut end of a fibro-vascular bundle forming one of the veins of the leaf.

cular system (*ribs* and *veins*) runs through the lower lax parenchyma (fig. 532, *f. b*), and consists of bundles of spiral vessels and liber, the former continuous with the medullary sheath (§ 666) and youngest part of the vascular axis of the stem, the latter continuous with the liber-bundle outside the cambium. The primary ribs in most Dicotyledons contain much liber, and thus become very thick, so as to project from the lower face of the leaf.

The primary ribs have a structure almost precisely like that of a small branch, though the cambium-layer or layer of active, growing cells is sometimes placed between the fibro-vascular bundles and the upper or inner epidermal layer in the case of leaf-organs, while in the case of the stem the organizing layer is situated between the fibro-vascular bundles and the lower or outer epidermis.

Great differences result from the different degrees of development of the spongy portion, as may be seen by comparing the leaf of the Lilac with that of the Aloe or *Mesembryanthemum* &c. The degree of consolidation of the epidermis by the formation of thickening layers (§ 637) is the principal source of difference of solidity of leaves.

686. Submerged leaves of aquatic plants have no stomata nor any extensive intercellular system; the epidermis is also little developed, and there is commonly a total absence of fibro-vascular veins; hence the delicate and perishable character of these organs.

687. The leaves and other appendicular organs are especially the seat of the glandular and analogous epidermal structures (§ 636).

688. The petioles usually consist of a mass of parenchyma, surrounded by epidermis and traversed by fibro-vascular bundles arranged in a more or less semicircular manner. When cylindrical the bundles form a complete circle, and the structure is then undistinguishable from that of a young branch, on which account the ordinary leaf has been regarded as a branch the upper portion of whose vascular tissues are suppressed or depauperated.

The fall of the leaf is effected by the gradual formation of a layer of thin-walled cells across the petiole, at right angles to the direction of the other tissues, and which thus ultimately separate the inert leaf from the living stem as by a knife-blade.

## *Structure of the Floral Organs.*

689. Bracts, sepals, petals, &c. are organized on the same plan as leaves, their epidermis frequently presenting raised conical cells and having stomata. The tissues of these organs are more delicate, the fibro-vascular structures being almost exclusively formed of spiral vessels. The parenchyma of petals contains fluid colouring-matters (§ 609) instead of chlorophyll.

In the parenchyma of the floral organs of coloured structures, the cells are filled with fluid colouring-matters of various tints, the depth of colour depending on the greater or smaller number of layers of colour-cells beneath the epidermis, the tints differing accordingly as cells containing colouring-matter of different hues overlie one another.

690. Stamens and pistils are composed of rather regular parenchyma with a delicate epidermis, and fibro-vascular ribs more or less developed in different cases.

The structure of the anther is somewhat complex, varying not only in different plants but also in different stages of growth. At first consisting of cells of about the same size and form, it subsequently presents a central mass devoted to the formation of the pollen (see under Physiology of Reproductive Organs). This central mass is overlain by three layers of cells: first in order going from within outwards is the *endothecium*, constituted by a single layer of delicate cells of a different size and shape from the rest, and usually disappearing as the pollen-grains are matured. These cells apparently contain nitrogenous contents, supposed to be applied to the nutrition of the pollen-cells during their growth. This layer is persistent in the case of anthers opening by pores. Succeeding the endothecium are one or more layers of permanent cells, some of which contain spiral fibres. These cells constitute the *mesothecium*. The fibrous cells vary in number and situation in different plants, and are sometimes entirely absent, as in the case of anthers opening by pores; hence they are supposed to act hygrometrically in the dehiscence of valvular anthers. The third layer of the anthers is of an epidermal character and is called the *exothecium*. The connective has the general structure of the filament; sometimes, as in some Lilies, it contains fibrous cells. Each cell of the anther is partly subdivided by cellular projections from the connective; to these processes M. Chatin gives the name of *placentoids*, being of opinion that they contribute to the nourishment of the pollen.

The pistils and fruits have, for the most part, the general structure of leaves. Some of their fibro-vascular bundles run along the placentas and give off spiral vessels through the funiculus (§ 234) to terminate at the chalaza (§ 236) of the ovule.

The style has usually in the centre a quantity of loosely packed, cylindrical, elongated cells, constituting the *conducting* tissue for the pollen-tubes. The stigmatic cells are devoid of epidermal covering, and hence present the form of partly detached prominences or papillæ.

The coats of the ovule, as well as the nucleus, are usually wholly cellular; occasionally, however, the vascular tissue, instead of ceasing at the chalaza, is prolonged upwards into the coats and into the nucleus. Great changes take place in the nature and arrangement of the cells as the ovules ripen into the seeds. The disposition of the cells of the outer investment of seeds is often very beautiful and characteristic.

In the ripening of the fruit the organizing tissues, which carry on the growth of the organ, are situated between the inner epidermal layer and the fibro-vascular zone, as in the case of leaves. Moreover the fibro-vascular bundles are arranged, as in the leaf-blade, with reference to a surface, and not in a cylindrical disposition as in stem-organs.

691. The anatomy of the thalamus or receptacle corresponds with that of the stem. Hollow receptacles, like those of the Rose or of

the Apple, in which the carpels are enclosed or imbedded, have essentially a stem-structure, their cambium-layer being placed between the fibro-vascular zone and the outer epidermis.

Anatomical investigations show that inferior ovaries (§ 158) are really cases of adhesion of the imbedded carpels to the expanded upper extremity of the thalamus.

# CHAPTER II.

## GROWTH AND DEVELOPMENT OF ORGANS.

### *Development of Cells.*

692. The cells originate in the interior of preexisting cells; but the phenomenon does not depend upon the cell-membrane; it is altogether a result of changes taking place in the cell-contents.

In the majority of cases cells are perfected within the cavity of the parent cell; but in the zoospores of the Algæ we have an example of the fully developed, newly individualized primordial utricle, with its contents, escaping from the parent cell in a naked condition, and forming its cell-membrane subsequently. Mirbel affirmed that cells were not in all cases formed within other cells; and recent observations tend strongly to confirm this opinion.

693. Development of cells in plants takes place in all cases in essentially the same way; but the form of the result is subject to a number of important modifications.

The modifications may be classed under two principal heads, in each of which class we meet with various subordinate varieties. These two modes of cell-development are:—1. *Cell-division*, where two or more new cells accurately fill the cavity of the parent cell and adhere firmly to its membrane, giving the appearance as though the original cell had been simply divided into compartments; and 2. *Free-cell formation*, in which the whole or part of the cell-contents become detached from the cell-wall and resolved into one or more new cells, which have no adhesion to the membrane of the parent cell, and ultimately escape from it.

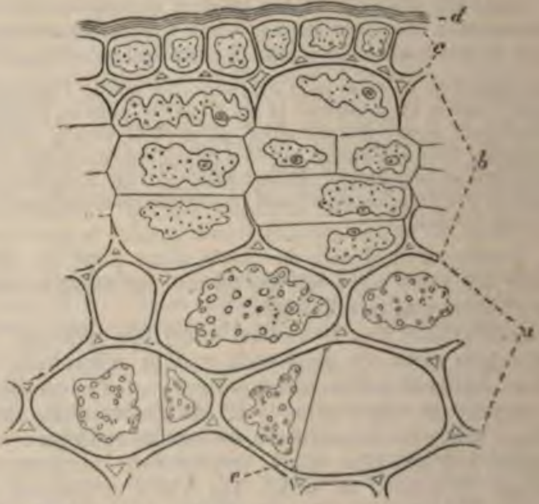
*Cell-division* is the process universal in the formation of the cells by which vegetative growth is effected; *Free-cell formation* occurs only in the production of cells connected with reproduction.

It will render the comprehension of the phenomena easier, to describe cell-formation first, although, from the statement just made, it is evident that free-cell formation is the primary phenomenon in the life of every plant that originates from a seed or spore.

Cell-division takes place in all growing parts of plants, but in the higher classes these regions are only accessible by dissection; in the lower, and especially aquatic plants, we are able to observe the process of cell-division in living organisms in all its details; and it is in these that the phenomena are most satisfactorily studied.

694. Cell-division can only take place in a cell which retains its protoplasm in an active state. When the parent cell is about to produce two (or four, or rarely more) new cells, the primordial utricle or protoplasm separates from the cell-wall at the line bounding the plane of division, and advances inwards in the form of a narrow fold, until the portions of the fold coming from the different sides of the cell coalesce, and the protoplasm is resolved into two (or more) closed utricles, together completely occupying the place of the original utricle. While the protoplasm is folding inward, it deposits at the same time successive layers of cellulose all over its surface; and these form thickening laminæ on the wall of the parent cell (to which they adhere), continued into a double septum separating the cavities of the two new cells, formed by the infolded portions of the protoplasm (fig. 533). This takes place not only in the vegetative cells but also in the pollen. At other times the

Fig. 533.

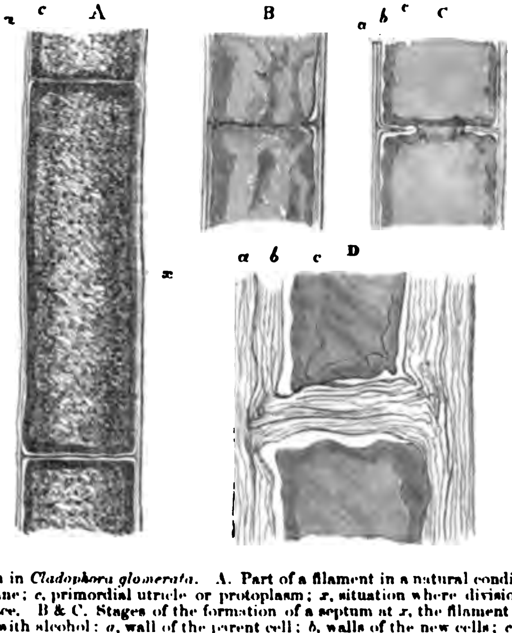


Section of the outer layers of the rind of *Cereus peruvianus* soaked in alcohol: *a*, cortical cells with contracted protoplasm, some with newly formed septa (*e*); *b*, cork cells newly formed by division in the outer cortical cells; *c*, epidermal cells; *d*, cuticle. Magn. 200 diam.

new dividing cell-wall is formed gradually, after the sudden division of the protoplasm into two portions.

This phenomenon may be traced very clearly in all its minutiæ in large species of Confervеæ (*Cladophora*, fig. 534); and so far as we may judge from observations, extended from similar cases, through the accessible structures (nascent leaves, prothallia, &c.) of Mosses, Ferns, &c., up to what we can detect in sections of the tissues of the Phanerogamia, it is the universal mode of subdivision of cells.

Fig. 534.



Cell-division in *Cladophora glomerata*. A. Part of a filament in a natural condition: *a*, cell-membrane; *c*, primordial utricle or protoplasm; *x*, situation where division is about to take place. B & C. Stages of the formation of a septum at *x*, the filament having been treated with alcohol: *a*, wall of the parent cell; *b*, walls of the new cells; *c*, protoplasm. D. Septum of old filament treated with dilute sulphuric acid, to swell up and separate the laminæ of the cell-wall and contract the protoplasm; *a*, wall of parent cell; *b*, wall of daughter cells; *c*, protoplasm. Magn. 200 diam.

695. The principal varieties which this process exhibits depend on the character of the tissue to which the dividing cell belongs. In filamentous Confervoids this division takes place in most cases both in the end cell of a filament (apical growth) and in cells forming links further down (intercalary growth); in each case the parent cell elongates more or less beyond the ordinary measure before dividing, and the new cells each grow until they equal the adult length of the parent. In the branched *Cladophoræ* (fig. 465, B) &c. the parent cell sends out a lateral arm, which is at first a pouch

with its cavity continuous with that of the parent; and this is subsequently shut off by a lateral septum formed in the manner above described. The *basidiospores* of the Agarics &c., and the spores of *Penicillium*, *Botrytis*, and the allied forms of Fungi, are produced in the same way, as also are the *conidia* of the "Yeast-fungus," the new cells emerging like bubbles blown out from the wall of the parent cell, and becoming subsequently shut off by a similar process. In the Phanerogamia, the cells of the growing points, as of the apex of buds and roots, of the cambium-layer of the stem, &c., multiply while very minute, so that it is not so easy to trace the changes; but cell-division may be readily observed in the epidermal hairs of the highest plants, and the protoplasm is observed to be equally efficient as the agent of multiplication in these. The direction in which the division takes place is usually horizontal, sometimes oblique, rarely if ever strictly vertical. It will readily be surmised that the form of the organs and the mode in which they ramify may depend materially on the form of the terminal or apical cells, and on the direction in which they divide.

The production of complete cells within cells, the septa dividing the new chambers being continuous with new laminæ deposited on the old wall of the parent cells, may not only be observed directly in *Cladophora* (fig. 534, D), but is beautifully proved by allowing filaments of *Spirogyra* to decay in water; but these break up into lengths of eight, four, and two cells, and at last into single short cells, by the solution of the membranes from without inwards.

The softening and swelling up of these parent membranes doubtless give rise to the semigelatinous coat of many of the lower Algæ, especially the *Nostochineæ* and *Palmelleæ*. In the cells of the parenchymatous tissues of the higher plants, their parent membranes are mostly lost sight of by being expanded to extreme tenuity, since the cells here usually increase very much in size after their first formation. In woody tissues, formed from cambium-cells, they are mostly so thin as to be almost imperceptible; but it appears as though in some instances they became transformed into a kind of cement gluing the cells together, but capable of being dissolved by nitric acid so as to set the wood-cells free.

696. Cell-division occurs as a forerunner of free-cell formation in many cases, when a tissue is about to give birth to a great number of free cells; as in the formation of the pollen-grains in anthers, and the spores in the sporanges of the higher Cryptogamia, where the structure is in the first instance developed into a quantity of chambers by cell-division, each of the compartments then producing a free cell.

This must be borne in mind presently, when we come to speak of the modifications of free-cell formation.

697. The essential character of *free-cell formation* lies in the circumstance that the protoplasm which produces the primary cellulose wall of the new cell previously becomes separated from the

wall of the parent cell, so that the new cell is free (or loose) in the cavity of the parent.

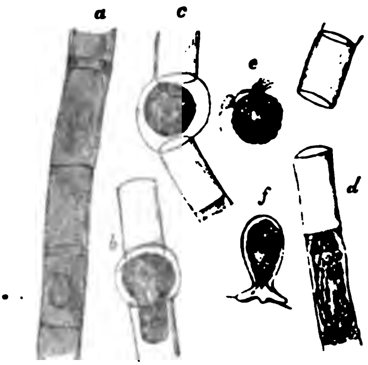
The modifications of free-cell formation are numerous.

698. The simplest case is where the protoplasm, enclosing *the whole contents* of the parent cell, separates all over from the wall of the parent cell, and, while thus free, produces a cellulose membrane over its whole surface, which constitutes the wall of a new cell.

This takes place in the formation of the parent cells of the pollen, in the cells of the parenchymatous tissues of the central region of the anther, and sometimes, but not always, in the formation of the pollen-grains. It appears to occur also in the formation of the parent cells of the spores of Mosses, Hepaticæ, Ferns, &c. It is more readily observed, accompanied, however, by special phenomena previously taking place in the "contents," in the formation of the resting-spores of the Confervoid Algæ. In *Œdogonium* the whole contents of the parent cell of the spore become isolated, and, secreting a new coat, form a free cell, which escapes by the dehiscence of the parent cell. The resting-spore of *Spirogyra* is formed in a similar manner, but around the blended contents of the two conjugated cells (fig. 465, A): the sporanges of Desmidiaceæ are formed in a similar manner.

The real character of the phenomena presented here is well illustrated by comparing the formation of the resting-spore of *Œdogonium* with the propagation of the same plant by zoospores (fig. 535). In the latter, the whole contents of a parent cell escape into the water (*b*, *c*) and assume a globular form, bounded simply by the primordial utricle or denser portion of the protoplasm (*e*), and it is only after a time that the cellulose membrane constituting the coat of the new cell is produced on the surface (*f*).

Fig. 535.



Development of zoospore in *Œdogonium*: *a*, parent filament; *b*, a joint breaking across to emit its contents; *c*, a more advanced stage (the globular mass of contents (nascent zoospore) still within a cellulose pellicle); *d*, empty parent-cell; *e*, the zoospore escaped from it, with its crown of cilia formed; *f*, the zoospore, after it has settled down, become encysted by a cellulose coat, and begun to grow into a new filament. Magn. 200 diam.

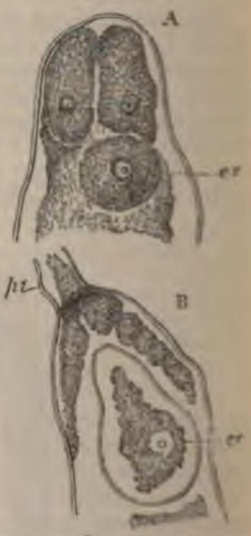
699. A case closely analogous to this is where *the whole contents of* the parent cell become parted into four or more portions, collectively filling the parent cell, but free from it, so that when they secrete their membranes they become so many free cells, which escape by the bursting or solution of the parent cell.

This case occurs frequently, with the production of four cells, in the development of pollen-grains and the spores of the higher Cryptogamia. Sometimes there is a certain irregularity in such cases, the parent cell either becoming really chambered by cell-division, and forming one cell in each of the four chambers, or at once giving birth to the four free cells.

Other instances of this modification are found in the development of the spores of the asci of Lichens and Mosses, apparently also in the tetraspores of Florideæ. The development in this way of new cells which escape from the parent cell as naked utricles, is observed in the spores of Fucus, and in the zoospores of many Confervoids, which are formed in fours in each cell (*Ulva, Coleochæte*, &c.).

The resolution of the whole contents of a cell into a great number of free cells occurs in the formation of the very numerous zoospores of *Cladophora* (fig. 465, c, *d*) and *Achlya*, with the formation of the new cell-membrane after their escape from the cavity of the parent; and what is observed in these cases leads to the conclusion that a similar mode of development, going on to the completion of the cells within the parent, occurs in the formation of the parent cells of the spermatozoids or antheridia of the higher Cryptogamia, where a great number of minute free cells are developed, and are found free in the cavity of a large parent cell. The formation of the new fronds of *Hydrodictyon* is a remarkable case of the resolution of the whole contents of a cell into a vast number of free cells, which acquire their cellulose coats and cohere into a new network within the parent cell.

Fig. 536.



Development of the embryonal vesicle of *Santalum album*. A. The upper end of the embryo-sac, with the embryonal corpuscles (*e v*) yet devoid of cell-membranes. B. The same later, with the pollen-tube (*p t*) adherent: the embryonal vesicle (*e v*) has acquired a cellulose coat. Magn. 400 diam.

700. In the formation of the germinal vesicles in the embryo-sac of the Phanerogamia, and probably in the cell corresponding to the embryo-sac in the archegonia of the higher Cryptogamia, *a portion only of the protoplasmic substance* of the parent cell takes part, becoming isolated in the form of one or more (usually three in Phanerogamia) globules (fig. 536, A), one (or sometimes two) of which acquires a cellulose

membrane, and forms the first cell of the embryo, or its suspensor (fig. 536, B). The new cell is here often very much smaller than the parent cell, and this case thus offers the clearest and most striking instance of free-cell formation.

In the embryo-sac of many of the Phanerogamia we observe, subsequently to impregnation, a process of free-cell formation of a peculiar kind, the protoplasm of the embryo-sac breaking up by degrees into numerous corpuscles, which successively form cellulose coats, and apply themselves to the wall of the embryo-sac, until the layers meet in the centre, and the whole sac is filled up with a parenchymatous tissue, the cells of which (*endosperm-cells*) are at first very loosely coherent. Perhaps the parent cells of the spermatozoids are formed in this way, in the cells of the antheridia of the higher Cryptogamia.

The formation of the active zoospore of *Vaucheria* is really a result of the isolation and individualization of a *portion* of the contents of the parent cell, since here the whole plant is one gigantic cell; but this case is quite different from the developments included in the preceding paragraph.

701. It is still a question what influence, if any, the cell-nucleus exercises over cell-formation; all that is certain is, that it exists in the majority of young cells, and that in many cases it divides (*Spirogyra*, hairs of *Tradescantia*), or disappears, and gives place to two (or more) new ones, just before or during the division of the primordial utricle to form the contents of two (or more) new cells. The real connexion of the nucleus with the life of the cell remains altogether obscure.

The original statements of Schleiden regarding the formation of new cells upon or around a nucleus were incorrect; the nucleus always lies under the primordial utricle, on which depend the structural conditions of cell-formation, and never in contact with the cell-membrane. But it is quite possible, and even probable, that the nucleus may have great physiological importance in cell-development, and may constitute the *focus*, as it were, of the physiological forces of the cell.

### *Development of vessels, epidermis, stomata, &c.*

702. The different forms of vascular tissue, including the laticiferous vessels, originate from cells. The most usual course is for a number of more or less oblong cells to range themselves end to end in longitudinal series; after a time the partitions between the cells are broken down or reabsorbed, and a continuous tube results.

The immediate inducing cause and the precise manner in which the partitions are absorbed are not known.

The epidermal cells are in the first instance usually smaller than the other parenchymatous cells, and more closely packed together. They are at first spherical or nearly so, but shortly assume the usual flattened character. The epidermis is at first destitute of *stomata* (§ 634); but these organs are gradually developed, in the following manner. In certain of the cells the nucleus, previously in contact with the cell-wall, becomes detached from it and subdivides into two nucleoli; the parent cell-wall then forms a septum between them; and thus two cells are formed, at first in apposition, but which subsequently separate and leave an opening (the *stoma*) between them. At the time that this is going on, wide intercellular spaces are formed, into which the stomata open.

### *Development of the Stem &c.*

703. The general course of development in the *stem* has been already alluded to in the case of the acrogenous, endogenous, and exogenous types respectively. Growth in length is effected through the agency of the *growing points*, which, when surrounded by leaf-scales and rudimentary leaves, form *buds.*

These buds, in the first instances, are little conical eminences consisting exclusively of cellular tissue, the constituent cells of which speedily range themselves in three divisions, which may be termed the central, cortical, and epidermal series. Of these, the central series forms the mass of the young bud; its cells divide at first in all directions, but subsequently in linear series; the epidermal cells divide by horizontal and parallel subdivisions; the cells of the intermediate cortical series, in the first instance, grow more after the fashion of the central cells. When leaves or branches commence to be formed, the outer cells of the central mass divide by longitudinal partitions, at the same time that the central mass itself exchanges its conical for a cylindrical form, ultimately constituting the medulla or pith. The form and position of these growing points depend materially on the form of the primordial cell, and on the direction (longitudinal, transverse, or oblique) of its partitions.

704. The form and mode of branching of the stem depend materially on the position and arrangement of the buds.

Misled by certain appearances well calculated to produce a false impression, botanists at one time attributed the formation of woody matters in root and stem to a progressive downward action: thus the new cells were supposed to be formed from above downwards. It is not necessary to state the arguments on which this theory was based, as it has been completely set aside by the researches of Trécul and others, which show that the new tissues are formed at the spot where they are seen, and are not formed from above downwards. Both bark and wood cooperate in the formation of new wood; and either of them may form woody or cortical tissues without the intervention of the other.

There is reason to believe that the growth of the stem of trees takes place principally in the summer months, and that comparatively little increase takes place either in spring or in autumn, though in the latter period the new growths are consolidated.

## *Development and Growth of the Root.*

705. The mode in which the root grows and is developed has been already treated of (§§ 680–682); but a few words may here be said as to the formation of adventitious roots.

These formations usually, but not universally, occur in places where the atmosphere is warm, stagnant, and loaded with moisture. If a ring-shaped piece of bark be taken from the stem, roots are formed from above the wound, but not from below—a circumstance supposed to be due to the accumulation of organizable matter above the wound; but by others it is considered to be owing to the absence of oxygen. Portions of willow-stems decorticated as above described and grown in water will produce roots below the incision if exposed to the light, and none above the water; and by covering the glass with black paper, and thus preventing the access of light, M. Böhm has succeeded in reversing the phenomenon. The portions of the stem in the water have been found by experiment to give out oxygen under the influence of light.

706. The downward direction of growth of the roots, as contrasted with the generally upward growth of the stem and its subdivisions, is one of the most remarkable phenomena of plant-life. In the case of the root, one principal reason for the downward growth is the greater amount of moisture received from that side. The root grows by development just within the apex; and the multiplication of the cells in that situation is dependent on a free supply of moisture. The instances of roots of trees growing in the direction of water-courses or drains illustrate this; and when plants are grown in close glass cases their roots are sometimes seen to rise above ground when the confined atmosphere is very moist. We have more than once observed the roots of bulbous plants, growing in water or in damp sand, coil themselves in spirals. Other assigned reasons are dependent on the circumstance that the soft yielding extremity of the young root penetrates the interstices of the soil, and is pushed down by the dilatation and expansion of the older portions above. The downward direction of the root-hairs, when present, would also facilitate downward growth, and prevent the root from being pushed up.

The action of gravitation has also been considered to have some influence over the downward growth, and also the varying degrees of tension manifested by the tissues in the different regions of the stem and of the root respectively, pith, rind, &c., such tension being directly dependent on the activity of the nutritive processes in the growing tissues. The combined action of the causes just mentioned is supposed to account for the varying direction and curvature of the organs of plants; but this explanation does not appear to be wholly satisfactory.

### *Development and Growth of Leaf-organs.*

707. The leaves (and all their metamorphosed forms, such as the parts of the flowers &c.) originate just beneath the absolute apex of the stem, by cell-division of the terminal cells—which results in the deflection to one side of a small group of cells forming a conical papilla, or the formation of an annular collar (sheathing leaves), which developes into an independent lateral organ. These leaves always arise *one after another*, in order regulated by the laws of Phyllotaxy (§ 60). The papillæ from which leaves originate are at first wholly cellular; after a time elongated cells are formed in the centre; and these are followed by spiral vessels formed in a direction from the base upwards.

As a rule, the first part of the leaf formed is its point, which is gradually pushed out by development at the point of junction of stem and leaf; but interstitial multiplication also occurs in different parts of the leaf (especially in stalked leaves).

The pushing-out of the leaf by development at its base may be well observed in the leaves of Hyacinth-bulbs developed in early spring. Not only are the tissues (epidermis, &c.) younger below, but the relative growth of the parts may be demonstrated by making a series of marks at equal distances up the leaf and watching the proportionate extent to which they become separated. The same process gives very instructive results when applied to the measurement of the growth of the roots of the same plants, and is easily carried out with bulbs grown in glasses of water.

708. The basilar or *basipetal* mode of leaf-formation above described is that which is most frequent; but in some instances the apex of the leaf, instead of early losing its power of growth, continues to grow and develope new cells in that situation, the cells at the base of the leaf, in these cases, being the oldest. This mode of leaf-formation is called *basifugal*.

These modes of leaf-formation may be well seen in the case of lobed or compound leaves. Thus in the Rose or Passion-flower the terminal leaflet is first formed, and the lateral leaflets afterwards from above downwards, according to the basipetal plan. In *Mahonia* and in many Leguminosæ, such as the Garden Pea, the lower leaflets are formed first and the others subsequently, according to the basifugal plan. The lobes or notches of simple leaves are in like manner formed in one or the other of the methods just alluded to. The stipules are often developed before the leaf-blade; when otherwise, they are probably lateral developments from the petiole rather than separate organs.

Sometimes the two modes of leaf-formation above described coexist in the same leaf; that is to say, the lobes of a leaf may be formed from above downwards, while the nerve passing into each of them gives off its branches from below upwards.

709. The opposition, alternation, or spiral arrangement of organs

depends on the period at which they are developed: thus, if two or more leaf-organs be developed at the same time and in equal degree, a whorl is produced; if the development be *successive*, not *simultaneous* as in the preceding instance, the organs are then arranged alternately or spirally.

The development of the several parts of the flower takes place after the same fashion as that just mentioned in the case of leaf-organs in general.

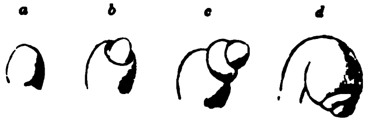
The causes producing irregularity and deviations from the typical floral symmetry have been already alluded to (§ 147 *et seqq.*). It should be remembered, however, that these irregularities are often congenital, *i. e.* exist from the very beginning; in other cases the symmetry is perfect at first, but becomes subsequently changed.

Usually the floral tubercles representing the origin of the several organs originate separately; but sometimes a cellular ring-like projection is first emitted from the stem, and from this sheath-like structure are evolved the floral organs.

Compound stamens (§ 199) or phalanges of stamens originate as simple tubercles, from the sides of which originate the secondary staminal tubercles from above downwards, as in Mallows, the whole course of development here precisely resembling what takes place in the compound leaves of some Passion-flowers or of the Rose.

The ovule arises from the placenta as a cellular papilla, the *nucleus* (fig. 537, *a*). Around the base of this is formed a cellular ring, which gradually lengthens from the base upward into a tubular sheath or coat of the ovule (*b*). The succeeding coats, which vary in number in different plants, are formed in like manner, are wholly cellular, and leave at the apex a small hole, the *micropyle* (§ 236). During the growth of the coats of the ovule a change in direction usually occurs, so that the ovule becomes inverted (§ 238). The structure and mode of development of the pollen and of the ovules will be further alluded to under the head of the Physiology of the Reproductive Organs.

Fig. 537.



Development of ovule: *a*, primary nucleus, invested at *b* by the *primine*, and this by the secundine (*c*); at *d* the ovule has become anatropous.

**From what has been said on the morphology, structure, and mode of development of the several organs, it will be seen that all the organs of flowering-plants may be reduced to two types—that of the axis, and that**

of the leaf; and, indeed, it is not possible in all cases to distinguish between stem-organ and leaf-organ. The distinguishing character least liable to exception consists in the circumstance that a bud may be and is constantly formed at the apex of a stem, while it is never developed from the apex of the leaf-organ. Another distinction consists in the relative position of the cambium layer (§ 685). Two opposite modes of growth, the definite and the indefinite, occur in stem-organ and in leaf-organ; and to one or the other of them may be referred all the variations in form and mode of development.

## CHAPTER III.

### GENERAL CONSIDERATIONS ON THE PHYSIOLOGY OF PLANTS.

710. What are termed physiological phenomena are manifestations of a peculiar force or forces, the presence of which in any body marks the existence of what is called *life* or vitality.

The vital force appears to present certain modifications. In plants there exists only an *organizing* power; while in animals there is superadded to this what is called *nervous force*, connected with the presence of a self-determining *will*, and, in the higher classes of animals, with a far greater subordination and mutual dependence of the organs than occurs in plants.

This statement is somewhat general, applying only to the two Kingdoms, Vegetable and Animal, as wholes; for there exist animals of simple organization exhibiting no more definite traces of the existence of a nervous force than we find in certain plants, or structures of plants. For example, it is scarcely possible to point out any important physiological difference between the zoospores of the Confervoids and the Protozoa such as *Amœba* and allied forms.

711. The *organizing* or *vital* force of plants is especially distinguished from that of animals by its relations to the chemical forces regulating the changes of inorganic or mineral matter. Plants are nourished directly on mineral food; animals can only assimilate substances which have entered into special combinations in the organisms of plants, and assumed the condition of what are called *organic compounds*.

Some plants live entirely on organic substances, as we see in the cases of parasites; and the power probably exists in plants generally to a certain extent. In the remarkable class of Fungi, almost all the kinds live upon dead or living organic matter. But the power of assimilating inorganic food is confined to plants, and is their most remarkable *positive* characteristic as contrasted with animals.

Another important distinction between plants and animals, as entire kingdoms, lies in the different disposition of their organs. In plants these are all produced externally: roots for absorption, leaves for respiration, &c., together with the reproductive organs, are all external. In animals the organs of "vegetative" life, *i. e.* of absorption, digestion, respiration, &c., are enclosed in the interior of the body, more and more completely in proportion to the complexity of the organization, the organs of motion and sense being thus brought out prominently externally. Animals feed by taking solid food into an internal cavity (stomach &c.) lined by absorbing structures; plants feed by sending their roots into the nourishing-matter and absorbing it, in a liquid or gaseous state, by their surface.

The proposed chemical distinctions between animals and plants must be taken with limitation. The cellulose structures or hard parts of plants have a peculiar ternary composition of carbon, oxygen, and hydrogen; but the protoplasmic matters contain nitrogen, and resemble animal matter.

Cellulose occurs in the structure of some animals (Tunicata); the green colouring-substance of *Hydra viridis* is undistinguishable from chlorophyll; and substances resembling starch in chemical properties are found here and there in animal bodies.

712. A very considerable part of the changes which accompany the process of organization are the results of the action of physical and chemical forces, capable of being explained up to a certain point by the known laws of those forces. But in every case, after referring all the chemical and physical phenomena to their respective places, there remains a residual phenomenon to be accounted for, which is precisely the most important of all, namely:—that in living organic structures (which are always recognizable by a definite form, structure, and composition) the laws of inorganic matter are, to all appearance, subdued under a higher influence, and caused to undergo modifications never occurring except in the presence of living matter; and the peculiar compounds of matter thus produced are not only made to assume forms, according to definite laws, totally unlike any forms of mineral substance, but constitute bodies manifesting a continued interchange of material with the surrounding media, which, instead of resulting in decomposition, as in mineral bodies, effects a reproduction and increase of the already existing matter.

The most striking characters of plants, contrasted with minerals, consist in the forms, and in the faculty of development and reproduction. As regards form, crystals exhibit regularity, obedient to certain definite laws, and so far might be compared with vegetable cells; some authors have even termed the cell a *crystal formed of substance capable of imbibition*. But there is an essential difference even in the structure of crystals and cells: the crystal consists of a combination of laminæ chemically homogeneous; the cell is a heterogeneous body, consisting in the simplest cases of a sac or excavated corpuscle containing in its cavity a substance differing chemically from the cell. Even in the imperfect free primordial utricles set free as zoospores in the Confervoids, this distinction of wall and contents exists; and it is still more marked in all complete vegetable cells, since these possess a distinct and persistent cellulose membrane.

The mode of formation of the cell, too, is essentially different from that of a crystal. The latter is formed by the simple deposition in a solid form of a compound dissolved in the "mother-liquor." The protoplasmic substance of plants (§ 597) can only be formed by protoplasm already existing, *selecting* and *assimilating* substances present in the surrounding medium, converting them into new compounds; while the cell-membrane itself, which is the part usually compared to the crystal, is likewise *produced* as a *new chemical compound* by the protoplasm, which secretes it in layers, unlike the protoplasm both in form, composition, and physical condition. When the true nature of the molecular constitution of the cell-wall and of the protoplasm is ascertained, it is probable that the statement in this paragraph will require considerable modification.

713. Organic structures are produced through the agency of like structures previously existing. Tissues increase by multiplication of the cells of which they are composed; cells are multiplied by the resolution of existing (parent) cells into a more or less numerous progeny of cells. Individual plants are multiplied by the separation of a portion of the substance of the parent plant endowed with a power of subsisting and developing itself independently.

The origin of organic beings from germs, *i. e.* more or less complex fragments detached from a parent plant or animal, endowed with a vital energy enabling them to reconstruct the entire organism, may be regarded as an undoubted fact, and it forms one of the most important of the differences between inorganic and organic bodies. As long as sulphur, oxygen, and hydrogen exist upon the earth, it will be possible for man to produce sulphuric acid; and if, in addition to these, he have sodium, he may cause the production of crystals of sulphate of soda at will. But although chemical analysis tells us that the mycelium of a fungus, such as "Yeast" or the "Vinegar-plant," consists of oxygen, hydrogen, carbon, and nitrogen, with small proportions of some other elements, by no means known or likely to be discovered can we cause the reproduction of these forms of vegetation, except by having recourse to the *germs* of the plants, and setting them to work to reproduce themselves. This has been proved by numerous careful experiments, and the idea of a *spontaneous generation* of organic bodies is now exploded. The origin of each species of plant or animal must be regarded as the result of a distinct act of creation. When, through unfavourable circumstances, all the individuals and all the *germs* of a species are destroyed, that species disappears from the globe*.

714. The organization of plants is regulated by a series of laws which exhibit different degrees of generality.

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* Since the publication of the first edition of this work renewed interest has been given to this question owing to the controversy between M. Pasteur and M. Pouchet and their respective adherents. The facts and arguments adduced by M. Pouchet go far in support of the doctrine of "heterogeny," and at any rate show that the above statement is too sweeping in its character. The student will do well to consider it to a large extent an open question, and to remember that, whichever view may ultimately be adopted, the miracle remains the same.

715. The most general law of all is that under which protoplasmic substance assimilates inorganic or, more rarely, organic matter, and produces the closed cellular sacs called vegetable cells (§ 562). This affects all vegetable structure whatsoever.

The Fungi and parasites live on organic matter; and this is probably the case to a great extent with cultivated plants grown with excess of organic manures. This will be referred to hereafter.

716. One degree less general are the laws regulating the *forms* of the cellular sacs or cells (§ 568).

These determine at the same time the specific form of the plant in the Unicellular Algæ.

717. Next follow the laws of development of the secondary deposits upon the walls of the cells (§ 579), which are valid throughout the whole Vegetable Kingdom, but more and more complex in the successively higher classes.

718. The laws of combination of the cells into *tissues* (§ 614) are a little less general, the diversity increasing here again in proportion to the higher position of the species.

719. The laws regulating the forms of organs are of very great importance and interest; and in these we have to distinguish two aspects, or, it may be said, two coexistent series.

720. The principal Classes of Plants (see p. 10) are characterized by respectively possessing a peculiar type or plan of combination of the organs, having not only a morphological but a physiological speciality. The type, more or less recognizable, is a mark of the existence of a common law of organization throughout each class.

721. Within the limits of the Classes exist almost infinite varieties of form, referable to morphological laws which have been investigated in the First Part of this work. A complicated but graduated and interconnected body of laws was there shown to regulate the variations of forms in plants generally.

722. Lastly, in the description of the Natural Orders of plants, it will have been recognized that there are still more special laws of development, causing the existence of resemblance in limited groups of species; and, beyond this, every species or kind of plant (§ 311) has its form and mode of life more or less definitely fixed and regulated by its special law of organization.

These reflections enable us to explain simply the terms higher and lower classes or species of plants. In the *Protococcus*, consisting of a simple cell, the specific law, that which determines the characteristic form, follows immediately on the first (§ 715) of those above indicated. In a *Conferva*, the second and third (§§ 716, 717) are both involved; and the specific law at once succeeds these. Proceeding step by step, we shall find species in which there is a diversity of forms of the cell and of tissues (higher Algæ); next, of these and an additional diversity of organs (leafy Cryptogamia); and then come into play the laws of the physiological and morphological types of combination of organs, which are most complicated in the Flowering Plants, in the development of which, however, from the original germ, or embryonal vesicle, we may trace, in a graduated series, the commencement of the operation of the successively less general laws of organization.

723. Not only do different plants display great diversities in structure and composition, but each individual plant offers more or less diverse characters at different periods of life.

Plants commence their independent individual life in the form of a cell or a group of cells separated from a parent organism. In the lower plants such cells, once fully developed, as *spores* or *gonidia*, are capable, under suitable circumstances, of growing up into complete plants. In the higher Classes these cells (*embryonal vesicles*, or the *primary cells of a leaf-bud*) go through the earlier stages of development connected with the parent organism, and are detached (as *seeds* or as *bulbils*, &c.) already provided with rudimentary organs of vegetation.

724. In those cases where the detached bodies are products of simple vegetative cell-division, they often proceed at once to grow up into new plants (*gonidia*, *zoospores*), but more frequently their vitality remains latent for a certain definite period (*bulbils*, *spores* of Mosses, Ferns, &c.); and when the body is a result of sexual reproduction, it almost always remains for a more or less indefinite period (capable of being shortened or prolonged within certain limits by external causes) in a state of rest (*seeds*, *resting-spores of Algæ*, &c.), and then undergoes peculiar internal changes before recommencing development (*germination*) in order to grow up into a new plant.

Seeds and resting-spores (and to a less extent the resting-organs produced in vegetative propagation, as *bulbs*, *tubers*, &c.) are organized in a manner especially adapted to preserve the latent vitality from injury by external influences. They can withstand great variations of heat or cold, especially in the absence of moisture. Most seeds will bear a temperature very far below freezing-point if kept dry, and many will even bear an exposure to 100° or 110° Fahr. in dry sand. Prolonged immersion in water at 120° kills most seeds, unless the skin is very thick and they contain oil instead of starch in the endosperm (§ 299). Some seeds will bear a short immersion in boiling water (*Veronica*); but the seeds of Cereals, Beans, Linseed, and other plants scarcely survive a 15 minutes' soaking in water of 110°, while they will bear 140° in steam, and 170° in dry air.

Some seeds naturally lose their vitality very soon; this is the case with the seeds of *Coffea*, *Magnolia*, &c.; while other instances are related in which it has been preserved for centuries. The cases related of the germination of Wheat taken from Egyptian Mummies are perhaps doubtful; but well-authenticated instances exist of long preservation.

The resting-spores of Confervoids (*Protococcus*) have been revived after remaining for years in herbaria; and it is in curious relation to their growth in shallow pools, often dry in summer, that the resting-spores of these plants appear to require to be dried before they will germinate. Mr. Munby has recently recorded (1869) that he found a bulb of a species of *Narcissus* sprouting in his herbarium after it had been gathered (in Algeria) upwards of twenty-two years. This bulb, removed into the greenhouse and potted, has since produced flowers.

725. Plants are subject to a periodicity in their vital phenomena, partly dependent on their own laws of growth, partly on the seasons in the climate where they grow. As dependent on special laws may be noted the differences between annual, biennial, and perennial plants (properly so called), between deciduous-leaved and evergreen trees, &c.

*Annual plants* are such as germinate from seed, produce their whole vegetable structure, flowers, fruit, and seed, and die away in one season, between spring and autumn; such are the summer annuals of our gardens. *Biennials* sprout from seed in one season, and bloom, bear fruit and seed, and die in the second; the Turnip, Carrot, *Œnothera biennis*, &c. are examples of this. *Perennial plants* exhibit several varieties of condition. *Herbaceous perennials* (like the Daisy, Primrose, Garden Flag, &c.) germinate in one season, and produce a subterraneous rhizome, of indefinite duration, which annually sends up a flowering shoot or shoots. Other perennial plants of this kind form one shoot which vegetates uninterruptedly for many years before it flowers (*Agave americana*, Talipot Palm, &c.); and after ripening its seeds the stem dies down, leaving usually a number of offsets from the axils of its leaves (*monocarpic perennials*).

*Woody perennials*, trees and shrubs, usually vegetate for several years before flowering, but are subject to periodic rest, throwing off their foliage and renewing it upon fresh shoots of the same stem every season; and when they flower, the operation exhausts their accumulated powers of development so little that they continue to flower periodically (every season if in favourable condition) throughout life.

The "habit" assumed by plants depends in some degree on external conditions. Thus many of our garden annuals are perennial in their native climates; for example, *Ricinus* (the Castor-oil plant), *Mirabilis*, and other genera are annual herbs with us, but perennial and even woody in warmer climates. And some annuals may be made to vegetate for more than one season by removing the flower-buds as they appear; in this way gardeners produce the so-called Tree-mignonnette. The Winter-corn of agriculturists is really an annual plant, sown in autumn to obtain stronger growth, and is not specifically different from Spring-corn, sown in spring and reaped in autumn. The common Cherry-tree retains its leaves during the whole year and becomes an *evergreen* in Ceylon; and many similar instances of changed habit, the result of altered condition, might be cited.

For further particulars respecting the duration of plants, refer to the Morphology of Stems, §§ 46–55.

726. Few perennial plants retain their appendicular organs beyond certain definite periods. Ordinary deciduous trees lose their leaves in autumn in our climate; and previously to their fall their organs undergo internal changes, in which the assimilated matters are, for the most part, removed and their green colour altered. They are generally cast off by a regular fracture where they join the stem (§§ 77, 688); in the Oak, Beech, and other trees they die in autumn, but do not fall away at once, often remaining, when not exposed to violent winds, until pushed off by the expansion of the stem in the next spring. Evergreen trees and shrubs retain their leaves green and living until the succeeding season, when the new leaf-buds expand, as in the Cherry-laurel, *Aucuba*, &c.; or, as in many Coniferæ, they remain attached to the stem for several years (*Araucaria imbricata*, *Thuja*, &c.). In some of these cases the so-called leaves are probably foliaceous branches. The leaves of arborescent Monocotyledons (Palms) are also of long duration. The parts of flowers and ripe fruits are likewise cast off in most cases, although the fruits from which seeds have escaped sometimes remain long attached in a dead condition (Conifers).

727. The axis (with its branches) is the only permanent part of the plant; and the unlimited duration of this is strictly dependent on the development of leaf-buds (§ 106 *et seqq.*). When a shoot ends in a blossom-bud, the growth of that branch of the axis is arrested, and the prolongation of life depends either on the axillary leaf-buds situated below or an *adventitious* bud.

728. The production of flowers and fruit is an exhausting process: it has just been noticed (§ 725) that annuals may be made to live several years by preventing them from flowering. The arrest of growth of the large and highly developed axes of monocarpic perennials (*Agave*, Talipot Palm, &c.) is a necessary consequence of the terminal bud producing blossom instead of leaves; but the formation of propagative offsets from the leaf-axils before death is strictly dependent on the degree of vigour possessed by the main axis at the time of flowering.

729. The duration of herbaceous perennials may be regarded as unlimited, since they are always placed in a position to form new absorbing organs (roots) in the vicinity of their buds. The duration of trees is also theoretically unlimited; and in many cases great age is attained; but ordinarily trees acquire increased vigour with age up to a certain point, and then begin to decline, a circumstance attributable to the increasing distance to which the buds are removed from the roots, the obstruction to the flow of sap, the local decay of the roots and trunk from external injuries, &c. Cuttings from old trees, if taken from sound shoots, may be made the foundation of new trees as vigorous as the parents were in their earlier years.

Palm-trees grow to an age of 200 years or more; the *Dracænæ* (Dragon-trees) of Teneriffe have been known as old trees for centuries. Oaks, Limes, Cedars, Yews, &c. are known to have lived many centuries; and other cases are on record of gigantic trees whose age, deduced from the number of rings of growth of the stems, would amount to upwards of 3000 years. The *Bertholletiæ* of Brazil, the *Adansoniæ* of Senegal, and the *Wellingtonia* or *Sequoia gigantea* of California (363 feet high and 31 feet in diameter at the base) are examples of this.

730. In herbaceous perennials the older parts of the plant die and decay in a limited period after the development of the new axes. In Dicotyledonous trees also, the older part, which is enclosed by the new layers, and becomes consolidated into heart-wood (§ 670), must be regarded as dead after a certain period, ceasing even to carry sap mechanically; and we see hollow trees of this Class living and growing, where the whole of the older part has been lost by decay, a living shell of wood constituting the bond of connexion between the roots and the growing branches of the axis.

This death of the older tissue is not so common in arborescent Monocotyledons; but it is observed in *Pandanus* (fig. 9), where the base of the stem and the old roots decay, new (adventitious) roots sprouting out from the living part of the trunk, in a continual advance upwards.

The death of a plant or part of a plant depends upon the death of the cells composing its tissues. The duration of the life of individual cells is very different, according to their position and function. Cells situated at growing-points (in buds, cambium-regions, tips of roots, &c.) are very transitory, since during active vegetation they are continually divided, as parent cells, into two or more new cells, part of which are left behind as *permanent cells*,—those situated at the periphery, or most advanced point, becoming in turn the *parent cells* of a new generation. The permanent cells become parts of parenchymatous, prosenchymatous, or vascular tissues in the vegetative organs, or parts of reproductive structures in flowers and fruits. Thus they run through a course of life dependent in each case on the laws of development of the plant, according to which its organs have a shorter or longer duration. The *death* of the organ or tissue in which they exist results from the cessation of the vital activity of the cells according to these laws; and their *decay*, from the now unopposed operation of simple chemical forces.

731. The principal vital phenomena exhibited by plants are connected either with the maintenance and increase of the individual organism, or with the production of special structures endowed with the power of growing up into new individuals when thrown off by the parent.

We say the *principal* vital phenomena, because there are some which we cannot strictly affirm to belong to either of the above classes, although there can be but little doubt that they are in some way related; of these are the movements of plants like the Sensitive-plants, the folding up of leaves or flowers, &c.

732. The processes of *vegetation*, or growth of the individual, are, from the peculiar organization of vegetables, connected with the processes of *reproduction*, properly so called, by the phenomenon of *multiplication* or *propagation* through natural or artificial separation of portions of the structure which might remain and form branches of the parent stock. This *vegetative propagation*, distinct in important anatomical and physiological characters from *sexual reproduction*, is found in all classes of plants, and from its importance in relation to cultivation deserves separate consideration.

The construction of plants from a number of like parts more or less physiologically independent allows of their being increased by mechanical subdivision of the parent "stock," which is effected by making cuttings &c. The same occurs in the propagation of plants by bulbs, tubers, &c. (§ 46 *et seqq.*). Through the abstract consideration of these cases have arisen some curious discussions as to the proper application of the term "individual" in plants. It is not worth while to enter into these nice metaphysical points; for practical purposes it is most convenient to regard as an individual every vegetable body possessing all the organs necessary for life, the parts of which, however numerous and frequently repeated they be, are organically coherent and have a definite collective form: thus we should regard the Oak-tree as an individual, and in like manner the colony of simple cells associated in the thallus of *Pediastrum* (fig. 462, B, *a*).

733. The Vegetative processes of plants are divisible under several heads, which, however, present many points of interconnexion.

*Nutrition*, properly so called, can only be said to go on in the protoplasmic matters found in the interior of cells, since it is these substances alone that exhibit phenomena of consumption and reparation. The tissues of plants are, under ordinary circumstances, never renewed; the only changes which they undergo are stages of progressive development of growth, succeeded sooner or later by decomposition.

*Development* or *organization* constitutes the most striking manifestation of the vegetative action; but this is a final result, prepared from, and incessantly accompanied by, phenomena which are results chiefly of the regulated action of physical and chemical forces.

The subsidiary operations of vegetation are—*absorption* of food, *diffusion* or *transmission* of fluid through the organic structure, *assimilation* of absorbed material, and, intimately connected with this, the so-called *respiration* and *transpiration*. *Secretion* is more nearly related to *development* than to the processes just enumerated. The relations of many of the secretions of plants are very obscure. Starch, chlorophyll, fixed oils, sugar, &c. are of course (§§ 602–608) intimately connected with the vegetative growth; but we have no clue to the importance, as regards the plant, of the essential oils, resins, alkaloids, &c.

734. The *Vegetative Propagation* of plants presents special modi-

fications connected with the peculiar conditions of organization in the different Classes; and there are some important considerations connected with the contrasts existing between the results of this and of sexual reproduction.

735. The *Sexual Reproduction* of plants offers a series of phenomena of much interest when viewed comparatively through the different great Classes; and the phenomena of *Hybridisation* and the influence of sexual reproduction in the maintenance of specific characters require especial notice from the vegetable physiologist.

As the Vegetative propagation is a process of vegetative life trenching on the region of reproduction, so many of the phenomena accompanying sexual reproduction are properly special vegetative actions induced by peculiar stimuli; among these are the phenomena of ripening of fruits and sporanges, the evolution of heat from flowers, the irritable movements of floral organs, &c. These and some other unclassed phenomena will be most conveniently examined apart. In the succeeding Chapters on Physiology we shall examine separately:—1, the processes of Vegetation; 2, the phenomena of vegetative Propagation; 3, the physiology of sexual Reproduction; and, 4, various unclassed phenomena met with in a more or less limited range of cases of vegetable life.

# CHAPTER IV.

## PHYSIOLOGY OF VEGETATION.

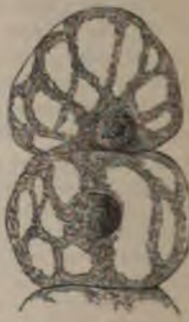
### Sect. 1. Cell-Life.

*Movements of the Protoplasm &c.*

736. Intimately connected with the early history of the protoplasm of the cell (§ 596) are certain physiological phenomena of the contents of individual cells, which will be most conveniently described here.

During the time when the protoplasmic contents of young cells are becoming gradually hollowed out into spaces filled with watery cell-sap (§ 599), a regular movement of this protoplasm takes place, which may be observed very readily in young hairs of Phanerogamic plants (fig. 497), and which probably takes place in an early stage in all other structures. This movement, which is erroneously called *rotation* of the *cell-sap*, is a circulatory movement of the protoplasm made perceptible by the minute opaque granules which exist in the colourless fluid. The nucleus is also carried slowly along in this movement, which, when the protoplasm has become converted into a mere network of cords, has the appearance of a system of reticular currents (fig. 538). This movement of the protoplasm ceases in most cells before they are full-grown; but in many aquatic plants, even of the class Phanerogamia, the protoplasm does not become excavated in the same way as it does in the cells of *hairs* &c., but applies itself as a thickish layer upon the inside of the cell-walls, and, retaining its activity, performs a rotatory movement around the wall of the cell permanently. In *Chara*, the moving layer of protoplasm is not applied upon the cell-wall: the primordial utricle, with the chlorophyll-corpuscles imbedded in it, lies on the cell-wall motionless; and a thick mucilaginous layer, situated between this and the central cavity filled with watery cell-sap, continually circulates.

Fig. 538.



Two apparent joints of a hair of the stamen of *Tradescantia*, with nuclei and reticulated currents of protoplasm. Mag. 250 diam.

The circulation in reticulated currents is most easily observed in young hairs of the higher plants. The movement of the parietal layer of protoplasm is made very visible in the leaves of *Vallisneria* by the green chlorophyll-corpuscles imbedded in it; and it may be well seen in *Anacharis*, in the delicate tissues of *Hydrocharis*, *Stratiotes*, &c. It occurs in the rootlets and other parts, as well as in the leaves. The phenomenon is most strikingly shown in the Characeæ, especially in the *Nitellæ*, which are simpler and hence more transparent forms.

This movement is only affected by substances that injure the healthy condition of the structure, such as chemical agents producing bursting or solution of the tissue, heat sufficient to cause coagulation or solution of contents, &c. In *Chara*, the large cells may be tied across, and yet the circulation be set up again in each of the chambers thus formed. Electrical currents do not affect it.

The movements in the protoplasm are attributed to various causes, such as contraction of certain portions of it, varying degrees of imbibition in different portions of the mass, the alternations in this wise giving rise to the currents. In many cases it has been definitely proved that the movement of the juices in which chlorophyll-granules are contained is directly dependent on the agency of light, especially of the more highly refrangible rays of the spectrum. Under the influence of diffused light the chlorophyll-granules range themselves parallel to the surface; but under that of direct light they are disposed on the lateral walls of the cells.

737. Analogous to the *rotation of the protoplasm* is the movement of the *ciliated zoospores* of the Algæ, and the *ciliated spermatozoids* or *antherozoids* of the higher Cryptogamia and the Algæ.

Zoospores are formed by the contents of vegetative cells becoming isolated from the cell-wall, and individualized into one (*Œdogonium*, fig. 535), a few (*Ulva*, *Ulothrix*, &c.), or numerous (*Cladophora*, fig. 465, c, and Phæosporeæ) corpuscles, which break out from the parent sac, and when free are seen to be provided with vibratile cilia (2, 4, or many), and to swim about actively for a period of from half an hour to several hours, then to settle down, become encysted by a cellulose membrane, reassume the characters of ordinary vegetable cells, and grow up into new plants by cell-division.

It has been observed that those zoospores with cilia at one end direct that extremity (which is destitute of chlorophyll) towards the light; and, moreover, the locomotion of these bodies is accompanied by a movement of rotation on their own axis.

Spermatozoids are filiform bodies of various forms, mostly presenting one or more spiral curves, or minute globules, and usually furnished with vibratile cilia. They are formed by a metamorphosis of the protoplasmic matter of cells developed for the purpose in the antheridia of the Cryptogamia. They are extremely minute, but move very actively when they escape from their parent cells, continuing to swim about for some time, being destined to find their way to the archegonium (or to the spores in Algæ), to perform the fertilization of the germ-cell. Many, however, never reach this, and they gradually dissolve away.

In the Volvocineæ (fig. 462, D), the separate primordial utricles lie imbedded in a common envelope, without a membranous cell-coat, retaining their vibratile cilia throughout life, only becoming encysted and formed into proper vegetable cells when converted into resting-spores. In the intimate affinity between these productions and the Protozoa, or lower Infusorial Animalcules, we perceive the close bond which exists between animal and vegetable organization when reduced to its lowest terms.

738. As long as a cell retains its active protoplasm, it is capable of producing new cells and organized forms of assimilated matter, like starch and chlorophyll, in its contents. This is the case, of course, in all nascent tissues; but it ceases to be so at various periods in different parts of the vegetable organization. In all woody tissues, in all pitted and spiral-fibrous cells, it disappears early, the secondary deposits of the ligneous character being formed apparently from the watery cell-sap. In herbaceous organs, such as leaves, in the cells of the Cellular plants generally, in fact in all the properly living structures, the protoplasm remains.

This explains why the power to form adventitious buds exists not only in the cambium-layer of the higher plants, but, under certain conditions, even in the leaves (as in *Bryophyllum*, *Gloxinia*, &c.), and why *gemmation* or propagation by little cellular bulbils, or isolated cells detached from the vegetative organs, is so common among the Cellular plants, and in the Mosses and Liverworts, where parenchymatous tissues so greatly predominate.

### *Nutrition in Cellular Plants.*

739. The elementary structures being essentially alike throughout the Vegetable Kingdom, and the physiological phenomena of vegetation depending almost entirely upon processes taking place in the individual cells, it is very instructive to examine the phenomena of nutrition and growth in those simply organized plants in which we are able to observe directly the changes in the living cells.

Many cellular aquatic plants are especially adapted for these researches, from their simple structure, transparency, and their aquatic habit, which permit us to keep them in a growing condition in glass cells beneath the microscope.

740. What is called the "Yeast-plant" consists of a particular form of the vegetable structure (*mycelium*) of a Fungus (fig. 468, A). It is composed of simple cells, which will go on multiplying by budding for an indefinite time if placed in a liquid containing a mixture of saccharine or dextrinous substances, together with albuminous matters, at a moderately warm temperature (59°–67° F.). These cells are simple membranous vesicles, with their walls formed of a modification of the compound (*cellulose*) of which all vegetable cell-membranes are formed. Within the cells exist nitrogenous matter in the condition of protoplasm (§ 597). The increase of the plant is dependent on the assimilation of substance requisite for the production of new cell-membranes, and of other substances to furnish new nitrogenous contents. When no material for forming cellulose exists, the plant cannot grow; but in solution of pure sugar, in the absence of any nitrogenous substance, the plant will multiply its cells for a certain time, the protoplasm of the old cells being transferred into the new ones as they are successively evolved. But under these latter circumstances the cells become gradually smaller, and at length cease to multiply, a portion of the nitrogenous matter being *wasted* in the reproduction until it becomes insufficient to carry on the growth.

On the other hand, if sufficient nitrogenous matter exists, the fermentation goes on, accompanied by the production of a more developed form of the *mycelium*, consisting of elongated interwoven filaments (the so-called Vinegar-plant); and development of this continues, if not interfered with, until the liquid consists of little else but pure water. The final form is the so-called "mother" of vinegar, which destroys the acetic acid.

741. The succession of phenomena here exhibited is connected with a series of chemical changes which are probably somewhat as follows. The whole of the processes are accompanied by evolution of carbonic acid (carbonic dioxide). The earlier growth can go on

without access of oxygen, as is evident from the fermentation proceeding in large vats with a stratum of carbonic acid several feet thick over the surface of the liquid; the growth in the latter stages takes place most freely with access of air. The original liquid contains grape-sugar (glucose), or dextrine, and nitrogenous matters. The action of the protoplasmic matter of the yeast decomposes a portion of this, forming cell-membranes. The chemical action here set up disturbs the combination in the rest of the sugar, which loses carbonic acid and becomes alcohol. If the growth of the Fungus continues, the alcohol becomes decomposed (seemingly by *contact-action* again), absorbs oxygen from the atmosphere, and becomes acetic acid.

It is not clear in most cases to what extent the Fungus is nourished on the alcohol, or on the saccharine or dextrinous matters mixed with the alcohol. To form cell-membrane from alcohol would require the absorption of a large quantity of oxygen, and the formation of much acetic acid and water. The growth of the Vinegar-plant in solution of sugar, then, would appear to cause simple liberation of water, while the contact-action in like manner decomposes the sugar into acetic acid. The "mother of vinegar" finally is developed at the expense of acetic acid, with separation of water.

The processes here briefly described cannot be disregarded when we inquire into the mode in which plants generally take up their food. Not only do the Fungi all feed in this way—as, for instance, the Dry-rot (*Merulius*), which lives on the dead substance of timber, or the parasites like *Pucciniæ*, the Potato-fungus, &c., which send their mycelium into the tissues of living plants to feed upon their juices—but the same laws evidently regulate the nutrition of the colourless parasites, such as Orobanchaceæ (page 332), and the Rhizanthous plants (page 360).

742. Following out this train of reasoning, we are irresistibly led to the conclusion that the same processes may occur in all plants under particular circumstances, although not absolutely necessary except at certain stages of growth.

In germination, doubtless the decomposition of the store of starch &c., with evolution of carbonic acid, during the recommencement of cell-development, is a phenomenon essentially similar to the development of the Yeast-plant. And we cannot find any reason to suppose that the roots of plants, which absorb all substances indifferently, can *refuse* to take up organic matters existing in a state of solution in the soil. The extent to which growth may be stimulated, without access of light, by profuse supplies of organic food, is strikingly illustrated by the many succulent vegetables cultivated for the table, such as Sea-kale, Celery, forced early Rhubarb, &c. And the tissues of the plants thus grown have exactly that weak, succulent character which is so striking in most leafless parasitic plants and Fungi.

Further applications of these facts will be dwelt on in the succeeding Sections.

743. In the above remarks we have considered only cases where Cellular plants appear to derive the material, both for their cellulose structures and their protoplasm, from organic substances, absorbed as such. By far the most striking phenomena of vegetative life are those in which inorganic matters are assimilated, and the gaseous and liquid constituents of the atmosphere and soil supply the requisite food.

If all plants required organic food, the organized substance upon the globe must continually decrease, since, as we have just seen, those which do live upon organic matter *waste* this through decomposition by *contact-action.* But the organic matter of soils upon which plants grow and decay in successive crops, undergoes continual increase, as we observe in the accumulation of vegetable-mould on undisturbed grass plains and in forests where the débris (fallen leaves, underwood, &c.) is not removed.

744. The majority of plants feed upon water, carbonic acid, and ammonia (and perhaps other nitrogenous compounds), with small quantities of various other elements, such as sulphur, phosphorus, and the salts of lime, potash, &c. Such plants can only flourish under the influence of light; and under this influence they produce, from the above materials, new cellulose &c. and protoplasmic matter. The assimilation is in such cases, as a general rule, accompanied by the assumption of a green colour, from the formation of chlorophyll.

Exceptions to the last assertion appear to exist in the red, olive, and other peculiarly coloured Algæ, in which no chlorophyll is produced; but we are totally ignorant of the processes which go on in the vegetation of these plants.

745. The history of the changes which take place in the cell-contents of the green Confervoid Algæ (fig. 465), which we are able to observe to a certain extent beneath the microscope, affords some material toward the comprehension of the processes which have their seat in the green parts of the higher plants.

We observe in the elongating apical or branching cells of the Confervoids, that the contents of the nascent parts (as in the upper half of the dividing-cell of *Œdogonium* &c.) are chiefly composed of colourless protoplasm, with watery cell-sap. Under the influence of light, green chlorophyll-corpuscles become more and more abundant; and under favourable circumstances of light &c. (accompanied by liberation of oxygen gas) the chlorophyll-corpuscles soon present starch-granules in the interior, which multiply and increase considerably in size. This formation of starch occurs chiefly after the cell has attained its full growth, and may be regarded as a continuation of the process which produced the cellulose of the cell-wall, now no longer required for the purposes of the individual cell, the contents of which, however, proceed with their assimilative action. After a time the cell prepares for propagation, or reproduction. Then the starch-granules disappear, apparently by solution into dextrinous or analogous matter requisite for the development of new cell-membrane, which soon takes place, either in cell-division (§ 694), or, if the primordial utricle is discharged from the parent cell in the form of zoospores (§ 698), in the formation of the cell-membranes of these bodies after they have come to rest.

Where resting-spores are to be formed, different changes ensue after the solution of the accumulated starch. The new cell, intended to remain in a quiescent condition, becomes coated by a cellulose membrane, or often two distinct concentric coats; and, at the same time, that portion of the contents consisting of dextrinous or analogous matter which has not been consumed in forming cell-membrane becomes converted into *fixed oil*, the green colour disappears, and the contents assume a red or brown colour, and external stimuli (light &c.) produce no influence. When these bodies germinate (which usually only occurs after they have been dried up and are again placed in water), the chlorophyll gradually reappears and the oil vanishes, and the entire course is run through again.

Comparing these phenomena with what we observe in the higher plants, we notice the similarity as regards the production of chlorophyll in the leaves, followed by the appearance of starch-granules as a form of *accumulated* nutriment. But the functions being more localized as the organization is more complicated, the starch thus formed is subsequently dissolved, and is carried away to the growing tissues of the plant, to the buds, cambium-region, and roots, where it is laid up in autumn, very often in this same form, but not unfrequently in the condition of fixed oil, as in the rhizomes of *Cyperus*, of *Lastræa Filix-mas*, &c., and, above all, in structures which, like the *resting-spores* above mentioned, are to remain quiescent while exposed to considerable diversity of external conditions, namely in seeds, as in the cotyledons of Cruciferæ, Almonds, Nuts, Walnuts, &c., or in the albumen of Poppies, Euphorbiaceæ, &c.

The oil (or starch in other cases) stored up in the seeds and rhizomes undergoes decomposition and solution in germination, to supply material for the cell-membranes of the nascent plant until the roots have become sufficiently developed to provide for it.

We have at present no very satisfactory evidence of the kind here brought forward to indicate the mode in which the nitrogenous matters, necessary for the formation of new protoplasm, are taken up. The question of the assimilation of nitrogenous matters will be considered in the following section, on the Food of plants.

## Sect. 2. Food of Plants.

746. The first step in the investigation of this subject is to ascertain what substances enter into the composition of vegetable structures and juices.

Analyses of plants have demonstrated the existence of the following chemical elements in plants:—Oxygen (O), Hydrogen (H), Carbon (C), Nitrogen (N), Chlorine (Cl), Bromine (Br), Iodine (I), Fluorine (F), Sulphur (S), Phosphorus (P), Silicon (Si), Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Aluminium (Al), Manganium (Mn), Iron (Fe), Zinc (Zn), Copper (Cu), Titanium (Ti), Arsenic (As), Lithium (Li), Rubidium (Rb), Cæsium (Cæ), and Barium (Ba).

All of these, however, do not exist in every vegetable substance: the first four are universally present, while a perfectly healthy condition cannot be assured unless sulphur, potassium, calcium, magnesium, iron, and phosphorus are also present at some time or other.

747. With the exception of *oxygen*, these elements are not taken up by plants in a simple form; and none of them exist as such in vegetable substances. The compounds of the different elements differ much in the proportion in which they exist. Water ($HO$ or $H_2O$) may form 90 to 95 per cent. Of the dry substance, compounds of carbon, hydrogen, and oxygen ($CHO$) may form 66 per cent.; the alkalies, earths, and metallic oxides commonly form 1 to 4 per cent., in rare cases as much as 20 per cent.

748. The great mass of all plants is composed of the first four elements in the list:—the solid parts, of compounds of carbon, hydrogen, and oxygen; the protoplasmic cell-contents (§ 597) of compounds of these three elements, with the addition of nitrogen. Sulphur and phosphorus appear to be necessary constituents also in the protoplasmic compounds; the alkalies and earths are, in most cases, requisite in the processes of elaboration, but may, in many cases, be substituted for one another (perhaps in certain cases may be replaced by ammonia); chlorine is necessary in many plants. Iodine and bromine are met with, particularly in marine plants; but it is not clear whether their presence is necessary, or merely an inevitable result of the absorption of sea-water. Iron and manganese are met with very commonly, copper and zinc more rarely; silicon abounds in certain Orders (Grasses, Equisetaceæ), and is met with in many plants in smaller proportions. The most necessary ingredients for the due nutrition of the plant are, in various proportions according to circumstances, a nitrate or an ammonia salt, a salt of potash, soda, lime, magnesia, and iron.

749. We have stated that (green) plants in general acquire their nitrogenous food by their roots (from the nitrates of the soil), and

their carbonaceous food by their leaves. The sources of the food are therefore the soil and atmosphere in which plants grow; and the inquiry presents itself at once as to the form in which the food is supplied to and taken up by plants.

On the one hand, we know that plants can absorb substances only in a liquid or gaseous form (§§ 755, 756); on the other, we know that both the atmosphere and the soil contain carbonic acid, water, and various nitrogenous compounds soluble in the latter. The alkalies, earths, &c. exist only in the soil, and in more or less abundance and more or less soluble forms in different cases.

Observation teaches us that the simpler plants, such as the Palmelleæ, Lichens, many Mosses, &c., can grow upon bare rocks or stones, and obtain their carbon, hydrogen, oxygen, and nitrogen from the atmosphere alone; and experiment shows that these are supplied in the form of carbonic acid, water, and ammonia: the substratum here supplies only the small proportion of mineral substance that is required. Moreover it is possible to grow a plant to maturity, and even to make it ripen its seed, in distilled water containing in solution only the ash-elements of aquatic plants, such as Confervas &c. Similar growth may be obtained by growing a plant in a watery solution of the necessary mineral ingredients of the plant, together with a nitrate or an ammonia salt, the excess of carbon in these cases being derived from the air.

Further, it is observed that, if a vegetation of this kind goes on undisturbed for a lengthened period, the decay of successive generations of plants leads to accumulation of organic substance, of vegetable mould, the material of which has been derived from the atmosphere by the plants, but has not been *consumed*, *i. e.* decomposed into its original forms of carbonic acid &c., by them and their successors.

From these facts it has been concluded, in the first place, and truly, that green plants have the power of feeding upon inorganic substances, and fixing them in definite organic compounds; secondly, but with less justice, that this is the universal law of vegetable nutrition—that plants live exclusively on inorganic substances, which they convert into organic matters unfit for their own use, and only assimilable after a new decomposition. In regard to certain plants this last assertion is altogether inadmissible, namely the Fungi and, above all, the colourless parasites (§ 741): and not only is it contradicted by the phenomena of their life, but it is opposed to the universal experience derived from observation of the cultivation of plants. Lastly, we know of no cause why plants should *refuse* to absorb organic substances presented to them in a state of solution favourable to endosmotic action in the roots.

It is very true that many even of the higher plants will grow upon soil almost destitute of organic matters, as we see on sandy heaths &c.; but the kind of vegetation which characterizes such soils is very different from that which clothes land covered with vegetable mould. And the influence of manures in agriculture must be attributed in a great measure to the extensive aid afforded to the plant in the shape of additional supplies of organic matters, which bear a kind of compound interest, since the increased growth they produce gives increased power of independent assimilative action.

750. Spontaneous vegetation is nourished principally by carbonic acid and ammonia always existing in sufficient proportions in the atmosphere. The former substance is taken up by the leaves; and the latter is also probably absorbed by the aërial organs of plants, since the lowest kinds have no roots; but the principal supply to the higher plants seems to be furnished through the soil, which receives ammonia dissolved in rain and dew, and, where porous, absorbs it greedily.

751. Plants growing upon soil abounding in decaying vegetable and animal matters are doubtless supplied with part of their food from these sources. Ammonia is a constant product of decomposition of animal substance, carbonic acid of this and vegetable matter. But from the researches of Mulder it would appear very probable that the old vegetable matters may pass into the living plants without undergoing decomposition into carbonic acid and water. The black decaying matter of vegetable origin, called *humus*, is decomposed in the soil into a series of organic acids, of which the last members possess much affinity for ammonia, and form both with it and the alkalies soluble salts, which may be absorbed as such by the roots. In favour of such a view is the fact that carbonate of ammonia (decomposable by crenic and apocrenic acids) appears in many cases hurtful when applied directly to the roots of plants. In addition to the tendency of these organic acids to attract ammonia, they seem to be capable even of causing its production in the soil, since, in the progressive oxidation of humus taking place at the expense of water ($H_2O$), the hydrogen of the latter possibly combines in its nascent state with the nitrogen of the atmosphere to form ammonia.

It has been common in recent works to find the value of humous or carbonaceous matters in the soil estimated very low; they have been regarded either as merely improving the (physically) absorbent power of soils, or as sources of carbonic acid, already sufficiently provided by the atmosphere. But the above observations, borne out by the experiments in Turnip-growing by Lawes and Gilbert, are in favour of a higher estimate of the value of decaying carbonaceous matters, and of regarding them as important constituents of farmyard-manures for certain purposes. Lawes and Gilbert found that stimulating nitrogenous manures in excess were rather detrimental to the growth of turnips, leaf-formation going on at the expense of the roots; but this was counteracted in a great measure by supplying, with the nitrogenous manures, carbonaceous substances in considerable proportion.

752. Certain observations made by Ville appear to indicate a power in living plants to fix nitrogen from atmospheric air; but this is negatived by Boussingault, Lawes and Gilbert, Pugh, and others. That ammonia is not absolutely necessary for the nitrogenous food of plants is distinctly indicated by the effect of nitrates as manures, rivalling that of salts of ammonia. Moreover it has been stated recently that *ozone* (a peculiar condition of oxygen) converts ammonia into nitrous acid; and there is reason to suppose that the ozone condition of oxygen is produced in certain cases in the liberation of that element by plants.

753. We may sum up briefly what appear to be the most probable hypotheses respecting the acquisition of the four principal elements (C, H, O, N) of the food of plants.

1. The cell-contents of plants, when they contain protoplasm, are capable of assimilating nitrogenous matters in the form of compounds of ammonia or nitrates.
2. Protoplasmic matters are capable of assimilating organic ternary compounds, without the aid of light, in the form of dextrinous or saccharine substances (Fungi), and in the form of compounds of the organic acids of the soil (crenic and apocrenic acids) with ammonia and alkalies. This action is accompanied by contact-action also, decomposing and wasting the organic matter (§ 741), when it goes on in Fungi or in other plants in the dark (germinating seeds, blanched vegetables, &c.).
3. Protoplasmic matters, in all plants except Fungi (and perhaps some Algæ), are capable of decomposing carbonic acid when exposed to sunlight, the carbon entering into union with the elements of water to form the ternary compound, C H O (dextrine, sugar, cellulose, starch, &c.).

754. For their mineral food, plants are of course chiefly dependent on the soil in which they grow. The gradual decomposition of rocks furnishes the earthy and alkaline constituents, which must vary on different formations or according to diluvial actions. Marine plants naturally accumulate many of the mineral elements of sea-water; and plants growing near the sea derive a certain amount of the salts of sea-water from the atmosphere, brought by the winds; the salt spray is shown to be carried great distances by its being injurious and destructive to many kinds of plants growing exposed to sea-winds.

### Sect. 3. ABSORPTION.

755. Since the lower plants consist of closed cells, in the interior of which their vitalized substance resides, and the membrane of their

cells, so far as our investigations can reach, is, in general, destitute of orifices, the food of these plants can only be taken up in a liquid or gaseous condition by the still mysterious process of imbibition.

756. In plants of more complex organization, although loose parenchymatous tissues exist, and the interspaces (§ 616) become concerned in at least *secretion*, the external surface of the plant, by which food must penetrate, is carefully guarded by a continuous epidermis, entirely devoid of orifices in the roots, the principal absorbing organs; and though perforated by stomatal orifices in the leaves and other aërial organs, these are carefully guarded by special contrivances to prevent the entrance of solid matter, and in all cases lead merely to *intercellular* passages, external to the membranes of the vegetative cells.

In the Fungi, Lichens, and Algæ absorption appears to take place freely at all points of the thallus to which gases and liquids have access. The structures of Mosses, Hepaticæ, and the smaller members of the higher groups of Cryptogams are likewise so simply cellular that they appear to be little dependent on root-structures.

In the higher Cryptogamia and the Phanerogamia the absorption of liquids appears to be confined to the roots, the epidermis of the leaves &c. being so organized as to oppose the entrance of water, while the stomatal cells which guard its orifices, swelling up so as to close the slit between them when filled with fluid, concur to prevent the absorption of water or other liquid. Gases, however, penetrate freely through most cell-membranes, and hence may be absorbed by leaves, and can pass freely through the stomata into the intercellular passages.

757. The physical phenomena of *diffusion* and *osmose* are the most important agents in the acquisition, by the cell-contents, of material from without. These phenomena depend, first, on adhesion of the liquid to the solid, and then on any circumstances which cause movement in the molecules of the liquid.

We may say, in general terms, that when two liquids of different densities (the one "*colloidal*" or little diffusible, the other "*crystalloid*," or greatly diffusible) are separated by a membrane or other porous substance, the denser liquid becomes increased in bulk by the passage of the thinner liquid into it through the membrane. This rule is indeed subject to modifications, dependent upon other qualities besides density of the liquids, such as their molecular relations to the substance of the separating membrane, the molecular nature of the membrane itself, &c., since, of two different liquids, that which is more readily imbibed by the membrane passes through in a preponderating current.

When we place simple vegetable cells with flexible cell-membranes, such as many pollen-grains, yeast-globules, &c., in water, their denser cell-contents absorb water and the cell-wall expands, sometimes even bursts. On the other hand, placed in strong solutions of sugar or gum, such cells will lose part of their contents and shrink. But these simple experiments are not sufficient to indicate what takes place in the cells of tissues filled with living protoplasmic matters; for very frequently, when we place such cells in liquids differing in density from their contents, there ensue successive changes of condition, which must also be involved in many natural processes. Thus, if we place in water a fragment of cellular tissue from the region where pollen-grains are being developed in the anther, or spores in sporanges, water is absorbed through the cellulose coat, but the primordial utricle contracts; but when the water penetrates the latter, it swells again and sometimes expands beyond its original volume, bursting the cell-membrane when this is weak.

The presence of a membranous or porous septum is not essential to such a process of filtration and admixture as above described. Two liquids of different densities placed in contact will gradually mix by the attractive force that the one exerts on the other. This *liquid diffusion* depends materially in amount on the nature of the liquids—colloid or crystalloid, as the case may be.

758. The recognition of *endosmose* as the cause of the absorption of liquids by the young roots and root-hairs affords some explanation of the apparently contradictory phenomena which have been described by those who have experimented with a view to ascertain whether plants have any *selecting-power*. It has been shown that there exist some very complex circumstances of purely physical nature in endosmotic processes, and that simple density of liquids is by no means the only important point—alkaline, acid, or neutral conditions of mineral salts causing special peculiarities, dependent on chemical and molecular relations to the membrane or porous interposed substance, and in other cases on chemical actions taking place on one or the other side of the membrane.

Some writers assert that the roots of plants absorb all substances indifferently; and the experiments of Vogel and others appear to bear this out. But, not to mention that the ashes of different plants grown in the same soil have different composition, Trinchinetti has shown that different salts are absorbed in different proportions from mixed solutions; and in De Saussure's experiments living roots absorbed differently from diseased or dead ones.

Such phenomena as these, however, may be explicable on purely physical principles. It has been proved that different chemical salts exhibit unlike quantitative phenomena in passing through dead endosmotic substances; and thus even from mixed fluids one salt might pass more readily into a cell than another; and, still more, the immediate decomposition of one salt alone, *inside* the membrane, while the other was not affected, which might take place in a living cell, would greatly affect the endosmose, since the cell-contents would soon be saturated with the latter, while the other would not accumulate. In regard to De Saussure's experiments (which are borne out by what we see beneath the microscope when we apply reagents, such as iodine, to healthy or decaying tissues), there is no necessity to have recourse to a vital agency of selection, since the chemical activity of the cell-contents, quite different in a living and in a dead organism, might account for all the diversities, even if the difference could not be explained by a physical difference of *tension* in the living cell-membrane and that of a dead organ, in which a process of decay immediately commences if it is exposed to the action of water. It has recently been shown that porous vessels placed in mixed solutions select, just as plants do under similar circumstances; and those solutions which pass most freely through the walls of cells are those which always pass most freely through the sides of the porous vessels. Those cases in which the same amount of any given substance is capable of being absorbed by plants which have nevertheless different chemical composition, may also be explained by the different osmotic powers possessed by the cells of different plants. Thus, supposing the root-cells of a cereal plant and those of a Leguminous plant to take up the same amount of silica from the soil, the quantity of that ingredient would speedily be found to be greater in the cereal than in the Leguminous plant, because the cells of the former can appropriate silica, and by osmosis store it up in the epidermal tissues, while the cells of the latter, having different osmotic relations to silica, soon become saturated, and can take up no more. On the same principle we see cells in juxtaposition containing very different ingredients, which yet do not mix because the conditions for endosmosis are in some way or other not favourable.

Schlosing says that the power of absorbing mineral ingredients from the soil is diminished by limiting the process of evaporation, as when plants are grown under a bell-glass.

759. The leaves and other green parts of the higher plants do not appear to absorb liquids. Whether they absorb even watery vapour to any great extent is questionable; but it is certain that they absorb gases, and that a very large proportion of the carbon which is consumed by green plants is taken into the system in the form of carbonic acid gas, by the leaves and green shoots.

Unger denies that leaves absorb watery vapour; but this is in contradiction to the general impression; and it is difficult to understand how they can *refuse* it. With regard to nitrogenous matters, there appears to be some reason to imagine that ammonia (or nitrates) may be assimilated by plants, and possibly by their leaves, from atmospheric air. This point will be noticed further on.

760. The entrance of gases into the cells is attributable, through their solubility in water, to endosmotic action; while the laws of diffusion of gases provide for their entrance into the intercellular passages, which brings them into contact with the deeper-seated cells.

## Sect. 4. Diffusion of Fluid in Plants.

761. The diffusion of the fluid absorbed by plants, and the nature of the interchanges which take place between the products elaborated in the different tissues, offer a number of problems, of some of which no very satisfactory solution can at present be offered.

762. In aquatic plants the entire surface is employed in absorp-

tion; and the liberation of gases in the respiratory or other processes being accompanied by condensation of the cell-contents, *endosmotic* action is kept up constantly during active vegetation.

In the Cellular plants, such as Lichens, Fungi, and even in Mosses and Hepaticæ, the diffusion of the fluids would appear to be a result of simple endosmotic action continued from cell to cell in more or less complex series; and in the plants growing in air, evaporation of gases increases the density of the contents of the last or uppermost cells of the chain.

763. In plants with well-developed stems and roots, the liquid nutriment is absorbed by the latter, and the movements which the absorbed fluids have to make are much more complex, not only from the greater variety of forms of tissue through which they have to pass, but from the multiplied details of the interchanges with elaborated matters arising from the scattered distribution of the leaves over the axis.

764. As so large a quantity of fluid is absorbed by the roots from below, it is clear that the diffusion of that fluid (or *sap*, as it is now called) must in the first instance be in an upward direction; hence the phrase *ascent of the sap*. The main current of the sap, then, is upwards from the root, through the stem and branches, to the leaves, wherein, owing to the changes it there undergoes and which will be hereafter alluded to, its character becomes altered and the general direction of its current reversed.

The upward direction of the *crude sap*, and still more the downward current of the *elaborated sap*, must be understood in a general sense as indicating the prevailing direction of the current. A more strictly correct expression would be to say that the sap, whether ascending or descending, moves in the direction in which circumstances are most favourable to its flow; and this is to those spots where the sap is most needed for the nutritive processes of the plant, as will be more fully explained in succeeding paragraphs.

765. The causes producing the ascent of the sap are manifold. They vary not only in their nature, but, at different times, in different parts of the same plant and under varying circumstances. We will first of all allude to the inducing causes separately, and then indicate how, when, and where they act. Endosmotic action consequent on the absorption of fluids by the root is on all hands admitted to play the principal share in the diffusion of fluids throughout the plant. Capillary action facilitates the upward passage in or between the fibro-vascular tissues. Pressure, whether exerted by the tension of the cell-walls upon their contents, and itself consequent on endosmosis, or as the result of increased temperature, which expands the air in the stem, forces the fluids to move in the direction of least resistance. The oscillations produced by the swaying of the branches, petioles, &c. by the wind also occasion intermittent pressure, to which

Mr. Herbert Spencer attributes an upward thrust of the sap towards the point of least obstruction.

The profuse evaporation or transpiration of watery vapour from the leaves is a powerful agent in producing an upward flow of fluid to replace that which is lost in the manner indicated. The extravasation or exudation of sap consequent on the mechanical strains effected by the wind also give rise to a current of sap from below. Chemical actions, such as the transformation of starch into sugar &c., necessitate a supply of water and create currents of that fluid.

The above-named causes act sometimes separately, at other times in combination. In the roots, not only the absorption but the ascent of the sap is due to osmotic action chiefly.

The roots take an important share in promoting the upward flow of the spring sap. If, in spring, we notice the surface of stumps of timber-trees which have been sawn off in the preceding autumn, we find the cut surfaces wet with abundant exudation from the outer layers of the wood; and experiments made upon the cut ends of branches, by Hales and others, show that the sap rises in them with very considerable force—in the case of the Vine, supporting a column of mercury 26 inches in height. It is evident, therefore, that the spring current, at least, is partly owing to absorption by the roots, in the cells of which decomposition and solution of starch are effected, and which must in consequence absorb water greedily; the engorgement of the tissues may cause the liquids to be forced into and upwards along the course of the vessels and ducts.

In woody stems osmose also comes into play in conjunction with capillary action and pressure dependent on the various causes before named. Pressure resulting from increased temperature is illustrated by the circumstance that the flow of sap in the trunks of trees is greatest during the daytime, when the trunk absorbs the sun's heat by its rough surface, and least at night, when the tree is cooled by radiation. In the leaves the transpiration and the movements effected by the wind afford the main causes for the rush of sap. In the expanding leaf-buds, and in all portions of the plant where vegetation is going on actively and where in consequence large quantities of nutriment are required, the chemical transformation of the cell-contents, which renders them available for nutritive purposes, necessitates a large quantity of water; and in consequence an endosmotic current is produced. This chemical action does not necessarily occur at the very point where growth is most active, generally, indeed, elsewhere, in what may be termed the store-cells, so that a current is determined from the store-cells to the growing points.

The transfers just alluded to may be compared to a row of firemen handing on pails of water, in the absence of a *hose* or continuous pipe, such as is represented by the blood-vessels of an animal.

The spring ascent of sap in Dicotyledons is partly to be accounted for by the solution of starch, or the decomposition of fixed oil &c., in the buds and cambium-region, as above mentioned (just as occurs in the root or in a seed beginning to germinate). But, as has been observed by von Mohl, the inspissated juices thus formed do not lie in the sap-wood wherein the ascending current flows, but in the cambium-layers where the elaborated sap *descends*; and it is not clear why the ascending fluid, if moved by endosmose alone, does not pass out laterally into the cambium as soon as it reaches the stem. That the buds, however, do exert this attractive force is seen by the influence of the heat of a greenhouse in causing the flow of sap in a Vine which is planted with its roots outside the house and its stem brought inside and trained there.

766. In the leaves (and green portions of plants generally) the very important phenomenon of evaporation or transpiration of watery vapours occurs, and constitutes probably the most important agent of all in causing the supply and diffusion of food in plants. It has been stated above (§ 758) that plants absorb their liquid food passively by their roots; therefore, under equal external conditions, a plant should receive the nutrient matters derived from its liquid food in the ratio of the quantity of water passing through its tissues and evaporated from its leaves &c., since the water passes off almost as pure vapour, and, at all events, leaves its mineral constituents behind. The amount of evaporation is remarkably great, and accounts in some degree for the sustenance of plants by such extremely dilute solutions of their nutrient matters as they find in the soil.

The experiments of Lawes and Gilbert give the following average daily loss of water in the months indicated, in pots of unmanured soil, the first line from *Wheat*, the second from *Peas*:—

| March 19th to March 28th. | March 28th to April 28th. | April 28th to May 25th. | May 25th to June 28th. | June 28th to July 28th. | July 28th to Aug. 11th. | Aug. 11th to Sept. 7th. |
|---|---|---|---|---|---|---|
| 14·3 | 40·9 | 162·4 | 1177·4 | 1535·3 | 1101·4 | 230·9 |
| 11·2 | 42·9 | 106·4 | 1079·8 | 2092·7 | 377·2 | — |

The total amount of water given off during the whole period of 172 days (March 19 to Sept. 7) was, by the *Wheat*, 113,527 grains, by the *Peas*, 109,082 grains. The total quantity of mineral ash from each of the samples was, *Wheat*, 36·49 grains, and *Peas* 43·16 grains, which shows that the Wheat took up 32·14 grains, and the Peas 39·57 grains of mineral matter in every 100,000 grains of water which evaporated from it.

The amount of transpiration depends on the age of the plant, the amount of surface exposed, the nature of the epidermis, the texture of the leaf, &c.; thus it is usually greatest on the lower surfaces of leaves, which are provided with the greatest number of stomata. External conditions, such as the degree of moisture in or the temperature of the air, also exert great influence on transpiration; the drier and hotter the atmosphere, the greater the transpiration. Light also has great effect on the quantity evaporated; but it is difficult to separate its effects from those of heat.

In the spring, before the expansion of the buds, absorption is necessarily greater than transpiration, the water in such a case is stored in the stem, where it is made available for the expanding buds and growing tissues generally. In the summer the transpiration is greater than the absorption; and then the leaves depend for their supply on the stores in the stem, or, failing that, they wither. Even in winter, provided the stem be not absolutely frozen, there is a motion of the juices, dependent to a great extent on the temperature of the soil, which is always in that season higher than that of the air, and it increases in amount from the surface downwards.

767. As regards the special tissues through which the sap flows, the experiments of Hoffmann and others indicate that a very uniform diffusion of fluids takes place in the Cellular plants and in the Mosses. But the last-named physiologist found that in the plants possessed of fibro-vascular bundles, the fluids passed up in the first instance from the roots chiefly in the prosenchymatous cellular constituents of the bundles. These experiments were made by causing the plants to absorb ferrocyanide of potassium; and then, by treating sections of them with a per-salt of iron, the course of the sap was shown by the local appearance of *Prussian blue.*

Unger's experiments, in which he caused plants to absorb the red juice of the berries of *Phytolacca*, gave the same results. As a rule, it was found by both observers that the fluids did not pass by the spiral vessels themselves, unless the continuity of the absorbing surface of the roots had been destroyed. Herbert Spencer's experiments, however, show that the passage through the vessels is much more rapid than through the cellular tissue. Where cut branches are caused to absorb, the fluids rise in the open vessels and ducts by simple capillarity.

768. The spiral and other vessels do not always participate in the diffusion of the juices; but in the commencement of the growing ing-season (with us, in spring), the whole tissue becoming gorged with fluid, the vessels are commonly found full of sap. In the regular steady course of vegetation the spiral vessels are usually found filled with air.

The *intercellular passages* are also filled with air, except under peculiar circumstances, and therefore take no part in the distribution of the sap.

769. The experiments which have been made to ascertain the course of the fluids absorbed by the roots, tend to show that the sap passes upward in the elongated cells associated with vessels in the fibro-vascular bundles, towards and into the leaves and other organs. The distribution of the fluids must therefore be very different in stems differently organized as regards the arrangement of these bundles. In Monocotyledons we find a series of isolated streams; in Dicotyledons the fluids ascend in a much freer and wider course, in the more abundant wood of the regularly arranged circle of bundles (§ 665). A further diversity arises from the changes which take place in stems with age: in Dicotyledons the inner layers of wood generally become converted in the course of time into *heart-wood* (§ 670), the solidity of which obstructs the passage of fluids, which then ascend chiefly in the outer, younger layers of wood, which constitute the *alburnum* or sap-wood.

This is illustrated by the vegetation of hollow Dicotyledonous trees, in which a sufficient layer of young wood remains within the bark to carry up the absorbed fluids. It is found that the careful removal of the heart-wood of trees does not prevent the supply of liquid to the branches from the roots; but if the layers of sap-wood are removed, the upper parts of the tree die from desiccation, even when the bark is left uninjured except to such an extent as is sufficient to allow of removing the wood beneath. The removal of a ring of bark does not prevent the ascent of fluid, but, as will be noticed presently, arrests the downward distribution.

770. A certain amount of lateral diffusion takes place from the ascending current, supplying the surrounding tissues with water, and, perhaps, nitrogenous materials; but this point is not clear.

771. The fluid which is found in the sap-wood of Dicotyledons is of a watery character, containing dextrine and sugar, but not starch, chlorophyll, or any colouring-matter. It contains also mineral salts absorbed by the roots, in an undecomposed condition, at considerable heights in the stem. These fluids are called *crude saps*, and occur in especial abundance at the time (spring) when the renewed chemical activity in the developing cellular tissues causes an increased absorption of fluids.

This *crude sap* flows out freely from incisions into the sap-wood of Dicotyledonous trees in spring, and sometimes spontaneously bursts forth in a kind of overflow, as in what gardeners call "bleeding" of Vines, Birches, &c.

772. The crude sap becomes more and more condensed as it ascends in the stem and other organs. In the leaves and other green parts it undergoes a most important transformation, loses by transpiration much of its water, and receives a new element in its composition, of the highest importance to it as material for development, namely carbon, derived from the carbonic acid absorbed by the leaves and decomposed there in sunlight, with the liberation of oxygen.

773. The nature of the progress of the sap thus elaborated from the leaves into the *cambium-region* (§ 666) of the stem and other parts is at present obscure. Some authors, indeed, totally deny that the elaborated sap does descend; but this is in contradiction to all experience and observation. All experiments which have been made favour the opinion that there is a descent of sap elaborated in the leaves, in Dicotyledons at least, in that part of the fibro-vascular bundles coinciding with the cambium-ring of the stem—that is, in the cambium-layer of the wood and in the internal tissue of the bark. This supplies the material for the development of new wood in the fibro-vascular layers; and this elaborated sap evidently passes not only downward, but also inward, by lateral transmission, since we find in autumn starch-granules laid up in the medullary rays between the wedges of developed wood.

The sap therefore performs a kind of circulation in Dicotyledons, not in a proper system of vessels, but by a series of disturbances and restorations of equilibrium in a mass of permeable tissues, dependent upon local physical, chemical, and developmental actions.

The evidence of a descent of elaborated sap is overwhelming. The simplest proof, that of removing a ring of bark, which causes the arrest of development of wood below the ring, is borne out by all variations of it. *Ringing* fruit-trees in this way causes a temporary increase of product of fruit *above* the wound, from the accumulation of the elaborated matter there. The formation of tubers in the Potato and similar plants is prevented by interrupting the continuity of the cortical layers; and when bark is removed in patches, and the surface becomes gradually grown over by new wood, the greater part of the new growth comes from the upperside.

It is Mulder's view, that all the nitrogenous constituents of plants are not only absorbed by the roots, but assimilated there at once, and that carbon is fixed in the green organs—then, that a continual interchange goes on from above and below, the roots supplying protoplasmic matters (§ 597) which originate all organic phenomena, while the leaves send down the ternary compounds (C H O) which afford the material for cell-membrane, starch, &c. This author attributes the distribution to simple endosmose; but this does not account for the passage of crude sap through the alburnum and of elaborated nutriment through the inner bark. Other authors consider that organic substances (carbo-hydrates, albuminoids, &c.) are formed in the leaves; in such a case a descent of the sap must of necessity occur.

774. Sachs states that the elaborated sap in the cellular tissue is different from that in the vascular; "the parenchymatous tissues have," says he, "an acid sap, containing sugar, starch, oil, vegetable acids," &c. The vascular and prosenchymatous tissues, including the "vasa propria" and clathrate cells (§§ 585, 624), have an alkaline sap. The sap passing through these tissues is of an albuminous nature. Other physiologists, however, doubt whether any such sharply defined dual nature of the elaborated sap exists, though admitting the large share which the vasa propria fill in the descent of the elaborated juices.

775. We may conclude this portion of the subject by repeating that the nutrient fluids in plants follow certain directions, according to the structure and arrangement of the tissues, the locality of the sources of nutriment and of growth or other action; and as regards the elaborated fluid the movement may be, 1, from the place of formation to that of consumption, or, 2, to the store-cells or reservoirs, or, 3, from these latter to the place of consumption. The ascending, descending, or horizontal direction of the current is therefore a secondary matter.

To illustrate the movement and transference of nutrient matters, allusion may here be made to the researches of M. A. Gris on the production and utilization of Starch &c. This observer finds that in winter-time the medullary rays, wood, and pith are all filled with starch-grains. These diminish in spring, but are afterwards replaced during the summer. He concludes from this that there are two special movements of the nutrient substances, as illustrated by their formation in summer and their absorption in the following spring.

## Sect. 5. ELABORATION OF THE FOOD.

776. When green plants are placed in water containing dissolved carbonic acid, and exposed to sunlight, they give off oxygen gas.

This may be readily observed in *Vallisneria* and other submerged green plants grown in glass jars, a continuous stream of bubbles escaping from the plants when standing in the sunshine. The frothy masses of Confervæ, borne up to the surface of freshwater pools in sunny weather, by the entangled bubbles of oxygen, afford another common instance.

The absorption of carbonic acid, and the elimination of oxygen in the case of aquatic plants, and also in that of leathery leaves as in the Cherry Laurel, where there are comparatively few stomata, take place on the upper surface only.

777. Where no carbonic acid exists, as in boiled or distilled water, no oxygen is liberated. Leafy shoots remaining attached to trees, but enclosed in close glass globes, increase the percentage of oxygen in the globes when exposed to daylight; and cut shoots with the lower ends placed in water containing carbonic acid in solution, give off more oxygen than if the lower ends dipped in water devoid of acid.

The oxygen exhaled by leaves &c. is formed at the moment of its liberation; for Confervæ, which have no air-passages, and other plants which have had their air-passages exhausted by the air-pump, give off oxygen under the above circumstances. Fragments of leaves perform the same function so long as their organization is uninjured, while the destruction of the cells by pressure &c. stops the action. The epidermal cells (§ 633) exhale no oxygen.

The unlike influence of the different rays of the spectrum is very remarkable. According to Draper, whose observations have been confirmed by numerous observers, sunlight acts in proportion to its illuminating power in the deoxidating process: which appears to be just the reverse of what occurs in the reducing action of light upon silver. The yellow rays are almost as powerful as white light: while the more refrangible rays, blue, violet, &c., have little or no effect on the emission of oxygen, though it is probable they may exert great influence on the chemical transformations which follow that process. In green light the leaves emit carbonic-acid gas, as in darkness. Diffused light is rich in the more refrangible rays, and hence causes a scanty emission of oxygen. Prillieux, however, asserts that the amount of oxygen emitted by light of different colours is in direct proportion to their illuminating-power, and that the effect of the yellow and red rays in causing the disengagement of oxygen is due to their luminous intensity. A corresponding fact has been noticed with regard to the evaporation of water, so that the two phenomena would appear to be in some way connected.

778. The quantity of oxygen given off bears a definite proportion to the carbonic acid absorbed by a plant; but excess of carbonic acid becomes obnoxious to health.

779. It would appear that nitrogen is also given off by plants exposed to sunlight. Draper observed considerable quantities exhaled; and Cloez and Gratiolet noticed more than was attributable to air accidentally present in the intercellular passages.

Boussingault asserts that in the case of marsh plants a small proportion of carbonic oxide is exhaled by the green parts of plants, but probably not under normal conditions.

780. When the influence of the sun is withheld from green plants, they cease to give off oxygen; carbonic acid is now not absorbed but exhaled, oxygen being absorbed from the surrounding medium.

Some entire plants (Fungi and parasites) and certain parts of most others (roots, flowers, germinating seeds, &c.) absorb oxygen at all times and exhale carbonic acid.

The carbonic acid given off from the interior of stems, roots, &c. by day is probably reabsorbed and decomposed in the green parts before it arrives at the surface of the leaves.

According to De Saussure, if a plant is kept in a perfectly closed jar containing a measured quantity of atmospheric air, for several days and nights (an equal number of each), no change is found in the volume or composition of the air; the plant has exhaled oxygen by day and absorbed it by night, and exhaled carbonic acid by night and decomposed it by day, in equal proportion. But if this plant is watered with solution of carbonic acid, or this gas is added to the air, the quantity of oxygen in the air becomes increased. Under ordinary circumstances the leaves decompose by day much more carbonic acid than they exhale by night. The disengagement of oxygen has been observed in some aquatic plants to go on in the dark for some hours after exposure to the sun. The sun's light is thus stored away in the plant and rendered available in some form or other when wanted.

781. If plants are placed under such circumstances that they cannot decompose carbonic acid and exhale oxygen (by excluding light from them), they never acquire proper development: no green colour appears (they are etiolated), little or no woody matter is formed in the walls of the cells, and the whole energy is consumed in pushing out weak watery shoots; scarcely any of the peculiar resinous, milky, or other secretions is produced; and plants can only subsist under these circumstances when supplied with organic nutriment.

We see this when shoots are developed from Potato-tubers in the dark, in the cultivation of Celery and other blanched plants, &c.

782. A moderate addition of carbonic acid to the food of a plant, with free access of light and air, is mostly accompanied by acceleration of the nutrient processes and a more abundant liberation of oxygen.

Many green plants will flourish in sunlight on water and carbonic acid alone. Saussure found that the organic matter of plants increased in the proportion of 2 to 1 of the carbon contained in the carbonic acid; the elements of water being combined with the carbon.

783. When plants are placed in pure nitrogen gas, or *in vacuo*, all the functions of vegetation are arrested; not only do the chemical actions above noticed cease, but irritability, like that of the Sensitive-plants &c., is lost, and the plant decays. Even shoots separately enclosed suffer in the same way. The death occurs especially early when the plant is kept in the dark.

This accounts in some degree for the injury resulting from roots growing down too deeply into the ground, as is often observed with fruit-trees.

784. It appears therefore that there are two opposed sets of operations in which plants have close and important relations to the atmosphere. In the one, occurring when they are exposed to the sun's light, carbon is fixed, which must be regarded as a process of *assimilation*. In the other, going on always in the dark, and during the day in many parts of plants, oxygen is absorbed and carbonic acid is exhaled, as in the *respiration* of animals. The former process is absolutely necessary for the production of new ternary compounds (C H O), but the latter appears absolutely requisite for the maintenance of the life of the plant.

The passage of gases, of whatever nature and in whichever direction, is dependent on the laws of diffusion; the cuticle of the leaf in these cases acts as a dialyzer or filter, checking evaporation, but permitting the passage of gases.

785. The assimilative process, in which oxygen is liberated, accompanied by accumulation of carbon in the tissues, is evidently related to the formation of the remarkable series of neutral ternary compounds which constitute the great bulk of the substance of plants, and, further, to the production of the more obscure and far more complex and varied series of substances formed by a further removal of oxygen from the compounds of the first class.

The composition of the principal constituents of cellular tissues, and the substances found in the watery cell-sap, is generally such that they may be regarded as consisting of carbon *plus* the elements of water; but it is by no means to be regarded as settled that they are secondary compounds formed by the union of water with carbon.

The formation of crystalline acids, such as oxalic acid &c., is theoretically accounted for by a process of deoxidation. A further deoxidation of carbonic-acid gas and water would result in the formation of the different carbo-hydrates, cellulose, starch, sugar, &c. A still greater loss of oxygen would account for the formation of vegetable fats &c.: thus from six equivalents of carbonic acid and five of water we may suppose starch, $C_6, H_{10}, O_5$, to be formed and 12 atoms of oxygen set free,

$$6CO_2+5H_2O=C_6, H_{10}, O_5+12O.$$

786. The formation of the neutral ternary compounds being con-

stantly in relation to the absorption of carbonic acid ($CO^2$) and the passage of water ($H_2O$) through the tissues, with the exhalation of oxygen, it has been assumed that assimilation of carbon in the green parts of plants is the result of decomposition of carbonic acid and of the combination of the carbon with water. As Liebig, however, indicated, water is far more easily decomposed than carbonic acid, and perhaps the oxygen may be derived from that, its hydrogen uniting with carbonic acid.

There is no evidence to show which view is correct. In the next place, Draper regards the decomposition of carbonic acid as a process resulting from *contact-action* or *fermentation* excited by the nitrogenous protoplasm, accompanied by a waste of the latter, in which nitrogen is liberated. Mulder, on the other hand, believes that the carbonic acid enters into combination with some substance existing in the protoplasm, and that the oxygen is set free by the decomposition of this compound; for example, that chlorophyll is produced continually in sunshine, the wax associated with this being formed from starch, accompanied by a separation of oxygen, that this oxygen partly escapes and partly oxidizes the chlorophyll substance, and causes it to become green.

Of these views, Draper's appears the most worthy of credit, as agreeing best with the phenomena observed in the cell-contents. Chlorophyll does not originate from starch, but usually *vice versâ*; and it is quite admissible to assume a deoxidating *contact-action* of the protoplasm under the influence of light, when we observe a distinct oxidizing *contact-action* of the same part of the cell-contents in the dark, as in the decomposition produced by the growth of the Yeast-plant (§ 740).

787. As to the nitrogenous constituents of plants, we know little at present beyond the fact that they originally exist in the form of protoplasmic substance, which, according to Mulder, consists of modifications of the substance called proteine, known as vegetable albumen, fibrine, caseine, &c. They constitute the substance of the primordial utricle (§ 596), the chief agent in development, and the protoplasm (§ 597), on which chiefly depend, in all probability, the vital and chemical activity of the cell-contents. These have the power of decomposing organic compounds by *contact-action*, and perhaps of causing new organic combinations. How they originate themselves is unknown; but it appears most probable that their source is either ammonia in combination with organic substances, or in some cases nitrates; and it is most probable that there is ground for Mulder's opinion that all actively vegetating cells (containing protoplasm) are capable of directly assimilating organic matters to some extent, whether exposed to light or not (§ 741).

This seems borne out by the universal presence of these nitrogenous compounds in actively vegetating cells, in roots, parts of the flower, in cambium, &c., as well as in green organs. That the *crude sap* (§ 771) is found to contain uncombined ammoniacal salts high up in the stem in spring may result from the activity of the currents of fluid allowing part of them to flow on undecomposed, while a part only is assimilated in the roots.

Proteinaceous matters, it may now be stated with some confidence, originate in the colourless protoplasm from the decomposition of sugar and ammonia salts in the same manner as starch is formed in the chlorophyll under the influence of light. Pasteur induced the formation of protoplasm in yeast-cells by supplying them with a saccharine solution and a nitrate or ammonia salt.

Our space compels us to restrict this Section within narrow limits, and we are obliged to omit any special reference to the application of these generalizations to the explanation of the facts of Agriculture*. The whole question is in a state of transition: much progress has been made in accumulating facts, but few points have been absolutely ascertained. The student is recommended to study works on physics and organic chemistry. Vegetable physiology is daily becoming more and more a subject for the physicist and chemist; and without a knowledge of the subjects treated of by students of these sciences, progress in vegetable physiology is impossible.

## Sect. 6. DEVELOPMENT AND SECRETION.

788. At the commencement of the periods of activity of plants, as when they shoot up from seeds, or when the new shoots are pushed out in spring, the whole product of the elaborating processes is devoted to the formation of new structure, to *development*. As the season advances the cell-forming activity slackens, the permanent tissues become consolidated by the formation of secondary deposits, and the parenchymatous tissues appear loaded with accumulated products of assimilation, such as chlorophyll, starch-granules, &c., which in annual plants are subsequently consumed in the maturation of the seeds, and in perennials are gathered together in autumn and stored up in those tissues which are to carry on the development in the succeeding season.

789. The phenomena of development have been sufficiently dwelt upon incidentally in preceding Sections (§§ 692–709 &c.); but we have still to speak of certain processes, occurring more or less extensively in plants, contemporaneously with development, in which products are formed which are not, like starch, chlorophyll, &c., evidently transitory forms of assimilated substance. These substances, called by the general name of *secretions*, are of most varied kinds, and their relation to the economy of vegetable life is still very obscure; but a brief notice of the most striking of them is indispensable.

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* The student will find a useful summary of chemical science applied to agriculture in a little work called 'How Crops grow' (MacMillan).

A distinction is sometimes made between the peculiar products found in the interior of cells, and those which are accumulated in certain cases in intercellular passages or cavities, or upon the outer surface of cell-membranes, the former being called *secretions* and the latter *excretions*.

790. The principal substances secreted by plants are air, water, gum, sugar, volatile oils, balsams, resins, gum-resins, and salts, either entirely inorganic, or formed of combinations of mineral bases with organic acids &c.; besides these there occur in individual Orders a multitude of alkaloids, neutral substances of various kinds, louring-principles, &c.

791. The liberation of gases in intercellular passages, cavities, &c. (§ 641) occurs both as a necessary accompaniment to the chemical decompositions going on in the cells, and as a special process connected with peculiar habit of plants &c., as in the *Utriculariæ* (§ 470), in the air-sacs of *Fucus vesiculosus*, &c. The composition of the air found in the cavities of plants necessarily depends upon the external conditions, as under sunlight there is generally a greater proportion of oxygen than exists in common air, in the dark but excess of carbonic acid.

792. Water is given off in a liquid form by various plants, either from glandular papillæ, or from the general surface of leaves &c. In *Nepenthes distillatoria*, *Sarracenia*, &c. water is secreted in the pitchers (§ 101) wherein it accumulates. The leaves of various Musaceæ, Araceæ, Grasses and other Monocotyledons, *Tropæolum*, *Impatiens*, *Brassica oleracea*, &c. give off drops of water from the leaves. In *Caladium* there exist orifices at the points of the leaves, communicating with internal canals, whence great quantities of water flow (half a pint in one night). This water is of course contaminated with salts and small quantities of soluble organic matters.

793. Gum is usually poured out into and accumulated in intercellular passages, as in the Cycadaceæ, in the bark of the Acacias, Cherry, &c. When it is formed in large quantities, it bursts the tissues and exudes in the form of tears. The formation of the gum Tragacanth in the species of *Astragalus* is different from this, consisting of collenchymatous thickening of the cells of the pith and medullary rays, which swell by absorption of water, and burst out from the stem under certain circumstances. The peculiar organs called *cystolithes* (§ 612) have a gummy excretion as a basis, in the form of a clavate body, suspended in the interior of an enlarged cell by a cellulose pedicle; when mature these bodies are covered with crystals of carbonate of lime; they are especially common in Urticaceæ, as in *Ficus elastica*, *Morus*, *Broussonetia*, &c.

794. Sugar, commonly occurring as one of the soluble forms of the assimilated ternary substances, is occasionally excreted, especially from the parts of flowers, such as the so-called nectaries. Through

evaporation of water the sugar sometimes appears in a crystalline form.

Sugar occurs commonly in the corolla-tubes of monopetalous flowers (Lilac &c.), on the nectariferous coronet of various plants, on the glands of petals like those of *Ranunculus*, *Parnassia*, &c., or in pits in the same situation, as in some Liliaceæ. On the leaves of various species of *Acacia* occur glands secreting sugar; and the same is the case in species of *Clerodendron*, Laurustinus, the lower surface of young leaves of *Prunus Laurocerasus*, &c. Various species of Ash (*Fraxinus*) and *Tamarix* excrete a great quantity of saccharine substance under the form of *manna*.

The wounds inflicted by insects (*Aphis*) also cause excretion of sugar from leaves, forming "honey-dew."

795. The volatile oils are extremely numerous. They are ordinarily secreted in glands (§ 645), either external or internal, situated on the herbaceous parts of plants. They are rarely pure substances, the essential oils usually containing dissolved resinous matters, camphor, or active principles of various kinds. The odours of plants and many of their most important qualities depend upon these secretions, which are generally peculiar to particular genera or Orders of plants, and not unfrequently differ in slight degrees, so as to be characteristic of particular species in an Order. The chemistry of the formation of these bodies is still very obscure. Some are hydrocarbons; others contain oxygen in addition; and sulphur plays an important part in many, especially in the Cruciferæ. The only general statement which can be made is, that the majority of the essential oils contain less oxygen in proportion to carbon and hydrogen than the dextrine and the other neutral ternary compounds, and that their production stands in a certain relation to the access of sunlight to the plants.

The Labiatæ with their external epidermal glands, the Hypericaceæ and Aurantiaceæ with their internal glands, the Umbelliferæ with the oleiferous vittæ in the fruit, the Terebinthaceæ, Rutaceæ, &c. are striking instances of the occurrence of essential oils in particular Orders.

796. Resins, solid or fluid (balsams), are very varied. They occur chiefly in intercellular passages, or in groups of cells especially devoted to the secretion of these products. Very little is known of the processes of their formation; but the same generalities apply to them as to the essential oils with which they are not unfrequently associated.

Among the resin-producing Orders may be noticed especially the Coniferæ, the Leguminosæ (*Copaifera*, *Myroxylon*, &c.), Amyridaceæ, Guttiferæ, Styraceæ, Terebinthaceæ, Liliaceæ (*Aloe*, *Xanthorrhea*), &c.

797. Resinous and waxy matters are found in considerable abundance on the surface of the leaves or fruits of many plants. It is not

clear at present how far these are to be regarded as proper excretions or as chemically metamophosed epidermal structures.

Under this head falls the waxy coat of leaves and fruits which exhibit what is called a "bloom," as the leaves of Primulaceæ (*P. Auricula*, &c.), Mesembryanthaceæ, the fruits of the Plum, Myricaceæ, &c. The wax of the Wax Palm (*Ceroxylon*) is formed in flakes upon the surface of the stem.

798. Wax and resinous matters occur on the outer coat of the pollen of flowers; and the viscid surface presented by the epidermis of many plants, such as *Lychnis Viscaria*, some *Silenes*, &c., is attributable to similar causes.

799. The so-called milky juices (latex) occurring in specially modified intercellular passages (§ 649) are of complex composition, containing essential oils, resins, gum-resins, starch-grains, extractive matters, alkaloids, proteinaceous compounds, &c. suspended in water, forming a kind of emulsion. They are not opaque and milky in their natural state, but become so when exposed to air, and mostly assume a transparent resinous character when their watery constituents evaporate.

Very different opinions have been expressed as to the nature of latex and the vessels containing it (§ 649). By some it has been considered a nutritive fluid analogous to arterial blood, by others as of purely excrementitious nature. A third notion is founded on the comparison of the fluid in question with venous blood. Probably that view by which it is regarded as a fluid containing, mixed with matters of a directly nutritive character, others which are excrementitious in their nature (Sachs, Hanstein) is the most correct. Trécul holds that the laticiferous vessels are the analogues of the veins, and their contents equivalent to venous blood. He traces a contact and inosculation of the laticiferous vessels with the pitted ducts and other vessels. Latex from this point of view would be the residue of the sap after elaboration by the cells—the *caput mortuum* of the sap.

These juices abound especially in particular Orders, as in the Papaveraceæ, Euphorbiaceæ, roots of Cichoraceæ, Apocynaceæ, Urticaceæ, &c. Amongst the most important substances obtained by evaporating them to dryness are:—*opium* from *Papaver somniferum*, and *caoutchouc* from various Euphorbiaceæ, Urticaceæ, and Apocynaceæ; *gutta percha* from *Isonandra gutta*, &c.

800. The saline and purely mineral excretions of plants have been already referred to. They occur as incrustations of the cell-membranes, as silica in the Grasses, Equisetaceæ, Stellatæ, &c., or carbonate of lime in *Charæ*, *Corallineæ*, and in smaller quantities on the leaves of various Saxifrages. Crystals (*raphides*, § 611), either of inorganic salts, or compounds of organic acids with lime &c., are frequently met with in the cellular tissues; but very little is known at

present of the nature of their relations to the chemical processes of vegetation.

The close relation of the vegetable organic acids, oxalic, malic, citric, &c., to carbonic acid, water, and the ternary assimilated substances has already been alluded to.

Tannic acid or tannin, $C_{27}H_{22}O_{17}$, is a very frequent constituent of the woody tissues when their vital activity has ceased, and is perhaps a product of decomposition. Oak, Sumach, *Rhus Coriaria*, *Acacia Catechu*, &c. owe their tanning-properties to this substance, which occurs more or less abundantly in all old structures of ligneous plants.

## CHAPTER V.

## REPRODUCTION OF PLANTS.

### Sect. 1. VEGETATIVE MULTIPLICATION.

801. It is a remarkable characteristic of the Vegetable Kingdom, shared, indeed, by some of the lower animals, such as Sponges, Polypes, &c., that their organizing forces are diffused throughout their structure, whence results not only great repetition of similar and, to a certain extent, independent parts in the same plant, but a capability in those parts of surviving when separated from the parent stock, and becoming the foundations of new plants. Through this condition of the organization arises the possibility of a *multiplication* of individual plants by simple subdivision of the vegetative structure of a single specimen—a process which is not only universal throughout the Vegetable Kingdom, but in many cases is so frequently and abundantly manifested as to throw the proper *reproduction* by seeds or spores into the background.

As will be seen hereafter, the spores of some Families are really formed by a kind of vegetative multiplication intermediate between the proper reproductive process and the development of the new plants; but it will be more convenient to examine those cases in connexion with the formation of spores and seeds generally, and to confine our attention here to what are distinctly and evidently bud-structures.

802. The modes of vegetative multiplication of plants necessarily depend essentially on the organization of the species; accordingly as the vegetative structures present more or less complexity, so are the "buds" more or less developed at the period when they are detached from the parent.

803. In the Thallophyta, where the entire organization is cellular, and no leaf-structures exist, the buds or *gemmæ* are cellular structures, more or less complex, according to the condition of the parent

thallus. We have examples of the simplest kind of multiplication in the lower Algæ, such as *Palmelleæ* (§§ 544, 549), *Desmidieæ* (§ 550), &c., where the plants are continually undergoing propagation by division of the constituent cells. In these cases such multiplication appears to represent the vegetative growth of higher forms, and a true reproduction, with formation of spores, recurs periodically to interrupt the simple cell-division, in a manner analogous to the recurrence of flowering, after a certain extent of vegetative growth, in the higher plants.

In the Fungi many kinds are abundantly propagated by *conidia*, or simple cells detached from the mycelium, as is the case in the growth of Yeast (fig. 468), in the propagation of the Vine-fungus, &c.; and in all probability the Fungi generally may be increased by artificial division of the thallus, as we see it practised in propagating the Mushroom, the Vinegar-plant, &c. In the Lichens there is a proper structure to which the vegetative multiplication is confined, viz. the *gonidia*, the green cells formed in the medullary layer of the thallus, which frequently break out from the surface and become free, especially when the plants are exposed to excessive damp. In the Algæ the vegetative multiplication exhibits very varied characters. In the Confervoids (p. 436) we have the *zoospores* (fig. 465, C, *d*, and fig. 535), as also in the Phæosporeæ: and the *tetraspores* of the Rhodospermeæ and Dictyotaceæ probably have the same import; but in addition to this, the thallus is commonly multiplied, especially in the larger forms, by the growth of a number of new thalli from the sides or the base of an old plant, and their subsequent separation by the decay of the parent thallus.

In the above cases we see the double representation of the vegetative process which occurs in so marked a manner in the higher plants. We have increase by simple and pure subdivision of ordinary vegetative structures, and, besides this, we see varied modifications of the vegetative cells specially organized to fit them for being thrown off spontaneously (*gonidia* &c.).

804. In the Hepaticæ and Mosses the propagative structures do not arrive at the condition of *buds*, although the parent plants have leafy stems. The *gemmæ* of these Classes are merely cellular nodules, more or less developed in different cases, and only acquire leaves after they have become independent. In the Jungermanniaceæ they are developed on the leaves, or in place of fruits. In Marchantiaceæ they are found in cup-like receptacles, being especially frequent when the plants grow in damp, shaded localities, a number of them (springing originally from a single cell) lying in the cup like eggs in a nest.

The Mosses produce *gemmæ* from all parts of their structures—from their leaves, stems, metamorphosed fruit-organs, and, above all, from thread-like runners which shoot out from the base of their stems. When their spores germinate, they also form first a mesh of confervoid filaments, each joint of which often gives birth to a leaf-bud (fig. 544).

805. The Ferns and allied Classes agree more closely with the Flowering plants in their vegetative propagation, forming leaf-buds in cases where they increase in this way; but there is a connexion with the Mosses &c. in the circumstance that their *gemmæ* appear more frequently on the leaves than is the case normally in the Phanerogamia—as, for example, in *Asplenium rhizophyllum*, where the leaves root and form buds at their tips, *Cystopteris bulbifera*, in which bulbils appear on the petiole, &c.

806. In the Phanerogamia the rule is, that every leaf-bud may be separated from the parent stock, and, if properly treated, reared into a new plant; moreover, in a vast number of cases, the leaf-buds are naturally modified in certain details of their structure, so as to protect them from external injury, and then thrown off spontaneously by the parents to multiply the kind. Many of the cases of this phenomenon have been described in the first part of this work under the head of Morphology of Stems (§ 46 *et seq.*) and Buds (§ 106 *et seq.*). We have there spoken also of the formation of *adventitious buds* (§ 109), and cited numerous examples, strongly indicating that relative independence of the parts of the organization of plants referred to above.

807. Adventitious buds are formed mostly when a plant or part of a plant loaded with assimilated nourishment is deprived of its natural developing-points. Thus we see abundant formation of adventitious buds on healthy trunks of trees which have been *pollarded*, *i. e.* have had their heads cut down so as to remove almost all their natural buds. The abundant supply of food existing in the trunk stimulates the cells of the *cambium-region* (§ 666) into extraordinary development, and true leaf-buds are produced, which form vents for the vital energy of the plant. This power exists even in the roots of many trees, as in *Maclura aurantiaca*, *Pyrus japonica*, &c., fragments of which in a healthy condition may be made to produce new plants.

Mention has been made of the formation of adventitions buds on leaves (§ 109), which has been observed frequently in wild plants, and is artificially induced in many cases as a means of propagation. As a rule, leaves are less prone to produce buds than stems or even roots, as might be expected from the more actively changing state of the contents of their tissues, and the usual absence of any great accumulation of assimilated substance, such as is regularly met with at certain periods in the stem and root.

That striking characteristic of vegetables which displays itself in the physiological independence of the leaf-buds, renders the vegetative propagation of plants a most important feature in their history, both in a natural and, in a still higher degree, in a cultivated condition.

A brief notice of some striking phenomena illustrative of the spontaneous propagation of the higher plants may be given here.

Various herbaceous plants are multiplied by spontaneously detached axillary leaf-buds; of this we have familiar examples in *Lilium bulbiferum*, *Dentaria bulbifera*, and the cultivated species of *Achimenes*. Similar propagative buds are often produced instead of flowers in the inflorescence of the species of *Allium* (Garlic &c.), both in a wild and cultivated condition; and the same is the case with some other plants, such as *Polygonum viviparum* &c.

The multiplication of *bulbs* by "cloves," or axillary bulbs produced in the axils of the scales of the parent bulbs, has been described in a former chapter (§ 47); and there also have been mentioned the structures called tubers, formed of modified stems, which are important agents in propagating the plants in which they occur. The Potato, for instance, forms tubers from its branches, the "eyes" or buds of which may be separated and made to produce each a new plant; and the Jerusalem Artichoke, Dahlia, &c. are similar in this respect. The terrestrial Orchids, such as *Orchis Morio* (fig. 20) &c., are not *multiplied* by their tubers, but only *continued* from year to year, since only one new "eye" is formed annually.

Still more frequent, perhaps, than the formation of bulbils, bulbs, or tubers, is the development of leafy shoots peculiarly organized for the purpose of propagating the plant which bears them, commonly comprehended under the names of offsets, stolons, runners, &c. Almost every gradation of condition occurs here, between the divisible rhizomes of such plants as the Daisy, Primrose, &c., the "runners" of the Strawberry, *Vallisneria*, *Hydrocharis*, &c., the offsets of House-leeks, *Stratiotes*, and the rosette-like stolons of *Epilobia*, &c., which approach to the axillary bulbils of *Achimenes*, and connect all these forms with the subterranean bulbs, corms, and tubers.

808. The artificial propagation of plants by division is effected by a variety of processes founded on the same physiological laws as the natural multiplication by detached buds &c.; it also includes a peculiar class of operations, in which the new plants are not converted into absolutely independent stocks, but are made to assume a pseudo-parasitical habit upon other plants, whose roots furnish them with that portion of their nourishment which is derived from the soil.

In the simple propagation, advantage is taken of the vital activity of the cambium-region to stimulate it to the production of roots, in the gardening processes of propagation by *slips* or *cuttings*, *layers*, &c. In the production of pseudo-parasites, as in *budding* and *grafting*, the woody structures of two distinct plants are made to become intimately blended by bringing into immediate contact the cambium-structures of both, at points where the cellular tissue is in an active state of development.

809. *Cuttings* or *slips* are ordinarily fragments of stems consisting of young wood, bearing one or more buds. These are planted in earth, and in some cases require no especial care to make them produce adventitious roots from the cambium-region, as in slips of Willows, and many common soft-wooded plants. Mostly, however, it is necessary to stimulate the vegetative action by a slight degree of artificial heat,—in all cases, however, guarding against drought; so that, as a general rule, cuttings are made to "strike" root best in an atmosphere where the watery vapour is confined by a glass covering. It is a matter of indifference whether a cutting having a number of "eyes" or buds is planted with the head upward or with the summit buried in the soil, and the lower part left free. In the latter case, the ordinary direction of growth of all the new shoots becomes reversed.

It has been stated above, that by careful management plants may be raised from cuttings of roots, and even from leaves (§§ 109, 807) made to produce adventitious buds by artificial stimulus.

810. Layers only differ from cuttings in the circumstance that the fragments to be detached are made to strike root before they are separated from the parent stock,—usually by bending down the branches and burying them in a portion of their course in the soil; an incision is usually made into the wood in the buried portion, which causes the more ready production of adventitious roots. An analogous operation is sometimes practised, in which a shoot is caused to root high above ground, by surrounding one or more of its nodes with a mass of earth kept moist by wet bandages or other means.

The artificial process of *laying*, practised commonly with Pinks, Verbenas, *Aucuba*, &c., is analogous to the natural propagation of the Strawberry by runners.

811. In all the cases comprehended in the above remarks, the adventitious roots are formed most readily in the vicinity of buds, at the nodes, just as we see them naturally occurring chiefly in those situations in creeping plants, such as the Sand-Sedge (fig. 24), Mint, many Grasses, &c., which root at every joint that comes into contact with moist soil, or in the climbing Ivy, in which the adventitious roots forming its organs of attachment to foreign bodies are produced in tufts a little below the leaves.

812. In the operations of *budding* and *grafting*, the parts of the parent plant are not made to form roots for themselves, so as to become altogether independent plants, but are caused to assume a kind of parasitical condition, in which they stand in the same relation to a strange "stock" as they would have held to their parent if left in their natural condition. The detached bud or shoot is made to contract an organic union with the cambium-region of a foreign stem, of which it becomes, as it were, a branch, deriving its supplies of root-

nourishment from it, and subsequently sending down in return elaborated juices to contribute to the sustenance of its foster-parent.

It is important to note, however, that in the case of distinct plants thus combined, they usually exercise no appreciable influence over each other in regard to modifying the *morphological* characters of each; the connexion merely affects the scion and stock in the degree of activity of the general physiological processes of nutrition &c. Scions grafted on stocks of more enduring character acquire greater vigour and fecundity; but the products of the buds of the scion in the great majority of cases resemble in kind those of their parent, while the stock continues to grow in its own way.

The influence of the scion on the stock, whatever it may be, is rendered less noticeable in practice from the fact that its buds or branches are always removed after the scion has "taken," in order to concentrate the sap in the latter; if allowed to develope, the branches of the stock formed below the scion mostly remain unaffected by the stranger which has settled above them.

813. A certain amount of physiological influence of the stock over the scion is shown to exist by such facts of horticultural experience as that the fruit of the Pear is smaller and more highly coloured when "worked on" the Quince or Medlar than when grafted on Pear-stocks, and is earlier when worked on the Mountain Ash. It is not clear here whether the alteration is attributable to greater or less vigour of the stocks, or to an influence obstructing the return of elaborated sap towards the roots, arising out of difference of texture of the wood. On the other hand, the scion has been in a few cases observed to affect the stock. It is well known that the variety of the Yellow Jasmine with variegated leaves, budded on a plant with healthy green leaves, causes the gradual appearance of variegation throughout the whole of the foliage of the plant. The same phenomenon has been witnessed repeatedly in the case of variegated kinds of *Abutilon*. If a variegated scion of *A. Thomsoni* be placed on a green-leaved stock, the new leaves pushed out from the latter become also variegated. If a green scion be placed on a stock of the variegated Abutilon, the new leaves of the scion become variegated. Further, if the variegated scion be removed from the green-leaved stock, the latter no longer produces variegated, but only green leaves. A still more striking phenomenon is the production of a hybrid Laburnum, by grafting *Cytisus purpureus* upon the common Laburnum. The cases seem well authenticated, and will be referred to under the head of Hybridation.

814. *Budding* consists in attaching the bud of one tree upon the developing wood of another. For this purpose the bud is removed from its parent with a slip of bark surrounding it, bearing on its inside a portion of the cambium-tissue existing at the line of

junction of the innermost region of the bark with the youngest wood (§ 666); this is applied upon the surface of a portion of the cambium-layer of the stock, exposed by slitting its bark and turning it back so as to form a kind of pocket. The slip of bark is inserted into this, so as to bring the cambium of bud and stock into complete contact, and the bark of the stock is then carefully bound down over the wound with bandages of bast, tape, &c. The organizing force resident in the cells of the cambium of the two portions causes them to grow firmly together.

815. In *Grafting*, a shoot instead of a bud is attached to the stock; and this is commonly effected by cutting off the head of the stock (or a branch of sufficient growth) with an oblique surface, or with a deep notch offering more than one oblique surface; the bottom of the shoot or graft is pared so as to fit accurately on the oblique surfaces, and in this way considerable tracts of the cambium-tissue and young wood are brought into contact—their cells, however, being partly end to end here, instead of side by side as in budding. Union of the growing region takes place exactly as in the former case.

Grafting is usually practised with young woody structures; but it is also successfully applied to herbaceous plants with careful management; and some Grasses even admit of being grafted on each other, although the operation is generally confined to Dicotyledonous plants.

What is termed *Inarching*, or "grafting by approach," may be compared to *laying* (§ 810): in this modification of the process, the scion is brought into union with the stock by bending over or otherwise, without being detached from its own stem, and the separation is not made until the scion has "taken" on its foster-parent &c.

816. It was at one time imagined that the annual layers of wood of Dicotyledonous stems grew down absolutely and mechanically from the buds, of which they were said to represent the roots. It was thought, also, that in the cases of grafts, the scions sent down woody structure over the old wood of the stock, so as at length to enclose it. From the description given above of the horizontal development of the cambium-layer of Dicotyledons, it will be seen that such notions are devoid of all ground. Merely fluid matters pass up and down in the cambium and bark, and the only reciprocal influence of stock and scion depends on the respective activities of roots and foliage.

817. The success of grafting depending on the contraction of intimate union between the cellular structure of the two plants, it cannot be found surprising that, as a rule, it is only between nearly related plants that such union is possible. If the size of the elementary organs, the rapidity or the extent of their periodical multiplication

and expansion, &c. are unequal, it is evident that no permanent coherence can exist: a tissue growing more rapidly would tear itself away from one less active. As a general rule, the elementary tissues agree closely in allied species, less closely in genera of the same Order, and are very diverse in different Orders; so we find that grafts take readily on stocks of their own species, to a considerable extent on stocks of allied species, and to some extent on stocks of genera belonging to the same Order. It does not appear that genera of distinct Orders have ever been grafted with success. The parasitic Mistletoe, however, attaches itself by a natural graft to Oaks, Apples, &c., and even to Coniferæ.

Some as yet unexplained exceptions exist to the inclination to union between allied genera. In some cases, also, a temporary union is effected, subsequently destroyed by unequal growth.

Among the Rosaceæ we see Pears grafted readily on Quinces, with more difficulty on Apples, and not at all on Plums or Cherries. Cherries and the Cherry-laurel readily unite. In the Oleaceæ we have the Lilac uniting with the Ash, the Olive with *Phillyrea*. It is extensively practised also with diverse species as well as varieties of *Rhododendron*. The Pear may be grafted on the Hawthorn; but the former grows so much faster than the latter that the communication between the two becomes interrupted in a few years at the point of junction.

818. The practices of grafting and budding are principally carried on, like propagation by slips &c., for the multiplication of varieties, which are, for the most part, grafted on other varieties, or normal specimens of their own species, these being far more healthy and permanent than those grafted on allied species. The multiplication of esteemed varieties of Roses, fruit-trees, &c. is chiefly effected by this means, the object being to produce specimens promising increased hardiness &c., or to obtain size and fertility earlier than could occur in a plant raised from a small cutting.

The Peach is worked on the Plum in Britain, because the latter is a native of this climate and is stimulated to growth in spring by a lower temperature than the Peach (from Persia); it does not succeed well here on Almond-stocks. The Pear seems to succeed better on Quince than on Pear-stocks in loamy soils; and other instances are well known to gardeners.

In addition to these circumstances, Pears, Apples, and other plants which may be easily grafted do not readily root from cuttings; moreover esteemed varieties of Rose &c. are quickly multiplied as "standards" &c. by budding them on briar-stocks already of several years' growth; and, in the case of new seedlings of fruit-trees, buds inserted on full-grown stocks are brought to flower and fruit in a few years, while, if left to grow up into trees alone, twenty years or more might elapse before they bore a crop.

Certain phenomena of grafting which are observed in practice cannot be fully explained by our present knowledge, but doubtless depend on causes similar to those just adverted to; among these are the facts that the Orange succeeds better on a Lemon stock than on one of its own species, while the Apricot does better on its own species than on the Plum, &c.

The influence of the physiological conditions of the stock upon the scion is turned to account by gardeners in producing a dwarfer "habit" and an earlier and more profuse production of fruit. Thus Apples grafted on the low-growing "Paradise stock" assume the dwarf habit of the stock and become more prolific. So Pears on the Quince-stock not only are dwarfed in size but produce fruit much more abundantly than when grown on their own roots or grafted on another kind of Pear. Gardeners often practise "ennobling" fruit-trees, where buds and grafts are attached upon stocks of good varieties of the plant in preference to wild stocks. Thus Apples are said to be much superior when grafted on stocks of good varieties instead of on Crabs &c.; and a kind of "crossing" of the qualities of varieties has been attempted on this principle, grafting kinds which bear sickly-flavoured Apples upon stocks of rougher varieties, Jargonelle and "mellow" Pears upon later, gritty varieties, &c. "Double grafting" is done when it is desired to secure a particular kind of fruit which will not unite or graft with the ordinary stock; thus a Pear may be grafted on a Quince-stock, and on the scion may be grafted another Pear, which will not unite directly with the Quince. Further details on the subject of grafting, a most important and interesting one, must be sought in horticultural works.

## Sect. 2. SEXUAL REPRODUCTION.

### *Preliminary Observations.*

819. In almost all plants the greater part of the active existence is passed in the development of vegetative organs, increasing the bulk of the individual, or occasionally also accompanied by multiplication of the plant by mere subdivision into parts. But at certain epochs another tendency manifests itself: the energies of the plant become concentrated in the formation of what are called reproductive organs, for the purpose of producing and maturing those independent germs of new individuals of the species, called *spores* and *seeds*.

The formation of reproductive structures bears a very interesting relation to the vegetative development. Generally speaking, the reproductive organs are only formed when the vegetative structures have become healthily developed so as to accumulate a certain amount of assimilated matter in the substance of the plant; we observe that many garden plants grown in unfavourable soil in shady localities &c. will not flower: and the number of years that elapse before the flowering of such plants as the Agave, Taliput Palm, &c. varies with the more or less favourable climate and soil; moreover in ordinary cases the flowering takes place at the close of the season of growth (except where the flowers emerge from buds provided for by the previous year's vegetation, as in Apples &c., in biennial and many perennial herbs). This indicates that vigour of the vegetative organs is a necessary condition of reproduction.

Further, reproduction is an exhausting process: it kills annuals; and excessive fruiting exhausts perennial plants.

At the same time the reproductive tendency and the vegetative tendency appear contrasted and opposed to each other; for reproduction is often retarded and replaced by rapid development of vegetative structures when plants are placed in too favourable a soil, especially when too freely supplied with water; and rankly growing plants are frequently made to flower by gardeners by cutting the roots, confining them in small pots, or limiting the supply of water.

820. The reproductive bodies produced by plants are either developed at certain epochs from structures originally belonging to the vegetative system, or they are formed in special organs. In the lower Algæ we find the cells, as those of the filaments of *Œdogonium* (fig. 535), or *Spirogyra* (fig. 465, A), originally true vegetative cells, and at a certain stage of growth resolved into reproductive cells and producing *spores* from their green contents. As we rise in the scale, among the Thallophytes, we soon find special cells (*Penicillium* &c., fig. 468), or groups of cells, exclusively vegetative or exclusively reproductive. In the higher Cryptogamia, assemblages of organs of various kinds are formed upon the stems, in which are ultimately ripened the *spores* of this group; while in the highest Class, the Phanerogamia, we meet with flowers containing stamens and pistils, ultimately producing true *seeds* in fruits which are totally separated in almost every case from the vegetative structures.

The spores of the higher Cryptogamia (Ferns, Mosses, &c.) cannot be properly compared to the seeds of the Flowering plants (that is, morphologically), since they result from a series of physiological processes different in many respects, as will presently be shown. With regard to the spores of the Thallophytes, our knowledge is too imperfect at present to enable us to decide upon all the homologies; the probable relations of the different kinds of structure will be incidentally spoken of in the next Section.

821. It is probable that representatives of two sexes, male and female, exist in all plants, and that these conjoin to form the rudiments of the new individuals of all Cryptogamia, as they do in the formation of the embryo in the seed of Flowering plants. But in the Thallophytes the male and female organs are often reduced to simple cells, "sperm-cell" and "germ-cell;" these being associated, often in the same plants, with "gonidial" cells (Algæ, Fungi) for vegetative propagation, the exact particulars and homologies are still obscure in many families.

The history of reproduction of plants has been greatly studied and much enlarged in late years; many important discoveries have been made in all Classes; and the course of the processes in Phanerogamia and the Leafy Cryptogamia is now pretty well known. Much still remains to be discovered in reference to the Thallophytes, especially the Lichens and Fungi; but in the Algæ the processes of fertilization of germ-cells by spermatic corpuscles have been observed more clearly and decisively than in any other plants.

## **Sect. 3.** REPRODUCTION OF THALLOPHYTES.

### *Fungi and Lichens.*

822. The various forms of reproductive organs met with in Fungi have already been described at p. 445. Most of them seem to be of the nature of buds; or if truly sexual, their operation has not yet been ascertained. The so-called *antheridia* and the *spermatia* have not been proved to be sexual organs. The phenomenon of conjugation in *Sizygites* and the process of fertilization in Saprolegnieæ, where a genuine process of impregnation takes place, have been described at p. 446. Similar phenomena have been described in *Peronospora* and *Cystopus*. In these plants there are female branches dilated at the end into a large globule or oogone, and male branches terminated by an ovoid extremity, flattened at one side and applied to the oogone. This antheridium emits a slender tube which pierces the walls of the oogone and reaches the central mass of protoplasm in the interior; and the latter, as a result of the contact, becomes invested with a cell-wall and forms a spore called an oospore.

The little that is known of the reproductive process in Lichens is alluded to at p. 442.

### *Algæ.*

823. This group takes a far more prominent place in the present Section, from the fact that organs to which a sexual function may be attributed have not only been observed in almost all its members, but the process of fertilization of the germ, the impregnation of the corpuscle produced by the female, has been directly observed in several of the Orders, namely Rhodospermeæ, Fucaceæ Confervoideæ, Diatomaceæ and Volvocineæ.

824. The Oscillatoriaceæ (p. 439) are at present only known to increase by division—that is, vegetatively; the Phæosporeæ (§ 548), again, are only known to propagate by liberation of zoospores from special cells of the thallus. The Dictyotaceæ and the Rhodospermeæ produce a peculiar kind of vegetative offset called a *tetraspore* (§ 546), a body formed mostly in special localities or in groups, and consisting of a parent cell divided into four chambers, the contents of which, when set free from the parent plant, grow up at once into a new thallus. Besides the tetraspores, they have *spores* and *antheridia*. The antheridia produce minute, ultimately free vesicles, *spermatozoids* or *antherozoids*, according to Thuret devoid of cilia and motionless; Derbès, however, asserts that he has observed them moving like undoubted spermatozoids. The *antheridia* are generally found in distinct plants from the *spores*, and the *tetraspores* in a third series of forms of the same species.

825. Where the sexuality of the Algæ has been ascertained, we meet with the process of fecundation under three different forms, and these forms in subordinate modifications. The three forms of the process are:—*Conjugation*, or complete union of a sperm-cell and a germ-cell, originally undistinguishable from each other by visible structure, occurring in Diatomaceæ and some Confervoideæ; *Fecundation of naked germ-corpuscles by ciliated spermatozoids*, which in the Confervoideæ occurs within the parent cell of the spore, and in Fucaceæ after both the germ-corpuscle and the spermatozoids have been cast off by the parent; and *Fecundation of naked germ-cells by motionless ovoid or globular spermatozoids through the medium of a special tube or trichogyne, as in* Rhodospermeæ. The importance of these phenomena to the whole theory of reproduction in plants renders it necessary to give a particular account of the processes as occurring in certain well-ascertained cases.

826. In Diatomaceæ (including the *Diatomeæ* and *Desmidieæ*), the ordinary mode of multiplication of the plants is vegetative propagation, *by division*, resulting either in the formation of connected "families" of cells (fig. 462, c) or of an increased number of separate cells, or by the *extrusion of zoospores*, which are developed into new cells or cell-families (fig. 462, B, *a*). This kind of propagation goes on actively for a time under favourable circumstances; and the mere "division," at least, may be compared to the vegetative development of more complex plants.

But at certain epochs this mode of increase is exchanged for another kind, in which we have cooperation of two originally distinct cells to produce the new one, indicating that it is a phenomenon of sexual reproduction, while at the same time there is no external evidence of difference in the concurrent cells. The genus *Closterium* (fig. 462, B, *c*) is multiplied vegetatively by division, or *fissiparous* propagation; at certain stages of existence, however, the cells which appear as if about to divide approach in pairs, and, a fracture of the external cell-membrane having taken place at the usual line of division, the contents of each cell, bounded by a primordial utricle, escape, come into contact with each other, and become confluent into a mass which assumes a rounded form (fig. 462, B, *d*). This round body becomes coated by a cellulose coat, and ultimately by a second, more internal. Its contents change from a green to a brown or yellowish colour; and the globular cell remains after the two empty parent cells have decayed. This globular body, which passes through a stage of rest before germinating, is sometimes called a *sporange*, not a simple spore, since its contents appear to become segmented and divide into a number of independent germs when the structure recommences active development.

An analogous conjugation of two cells takes place throughout the

*Desmidieæ*, and it has also been observed in many *Diatomeæ*; in all cases the product is a resting sporangial cell or frustule, *i. e.* a cell possessing more than one firm coat, which produces two or more germs when about to throw off these coats to develope into a new plant of the form of the parent.

Conjugation exhibits many minor variations in the groups of *Desmidieæ* and *Diatomeæ*; but it is necessary to restrict ourselves here to a general account of the process.

827. In *Spirogyra* (fig. 465, A, *a*), *Zygnema*, and one or two other genera of filamentous Confervoids ordinary growth by cell-division is exchanged for a process of conjugation at certain epochs. Two filaments, lying side by side (fig. 465, A, *b*), exhibit papillary elevations of the cell-walls on the sides next their neighbours; these processes elongate until they come into contact; they then adhere, and the septum formed at the plane of union becomes absorbed, so that the two cells become connected by a tubular process, a kind of isthmus. The contents of the cells meanwhile retract themselves from the wall, lose their spiral appearance, and become condensed into a mass; then, in some cases, the whole contents of one cell travel through the isthmus into the opposite cell (*c*); in others, the contents of both pass into the isthmus, which expands into a globular cavity in the middle. In either case the contents of the two cells become combined, and they form a globular or oval spore, which produces two or three firm coats, enters a stage of rest, and remains after the parent filaments have decayed away (fig. 465, A, *d*). After a time, usually in the spring succeeding the formation of the spore, this germinates, bursting its coats and sprouting out into a new filament like the parent (fig. 465, A, *e*).

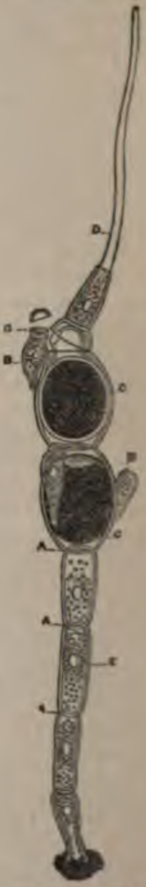
This conjugation of *Spirogyra* and its allies has long been known, and was without a parallel for many years; as stated above, an analogous process occurs in *Diatomeæ* and *Desmidieæ*, and it is essentially related to the processes of fecundation by spermatozoids next to be described.

828. The history of the fertilization in *Œdogonium* is one of the most curious points in the whole range of vegetable physiology, especially so as regards the male organs, which undergo a complex course of development as follows. On the same plant that produces the female spore, or in some species on another individual, are formed special cells called "microgonidia" or "androspores." The office of these cells is to produce ultimately antheridia, in which latter spermatozoids are formed. The androspores are formed in the ordinary cells of the plant, and escape from them by rupture of the walls of the parent cell as an ordinary zoospore would do, and like it they swim about in the water for a time; but while an ordinary zoospore after a time germinates and forms a new thallus, the androspores attach themselves to the sides of the female spore or sporangium.

In this situation they grow into a sort of prothallus; the lower part becomes dilated or pear-shaped, while the upper extremity developes one or two small cells one over the other. These are the antheridia; and in each of them is formed a spermatozoid, the fecundating body. These latter, when mature, are ciliated and butt against the top of the antheridium, and at length cause its detachment in the shape of a little lid. In this manner they escape from the antheridium, move about for a time in the water by means of their cilia, and ultimately pass into the female spore through an opening previously specially prepared for its passage in the summit of the female spore. Here the spermatozoid comes into contact with a quantity of colourless granular mucilage formed in that situation prior to fecundation, the distention consequent on which seems to account for the formation of the aperture through which the fecundating body passes. The spermatozoid touches the mucilage, or even penetrates it to some extent, and becomes blended with it and thus fertilizes the spore, which subsequently becomes invested by a cell-wall in the ordinary way.

829. *Vaucheria* is a genus of filamentous Confervoid Algæ, in which the long branched filament consists of a single enormously developed cell. This plant is commonly propagated by a peculiar kind of zoospore discharged from the thickened end of the filament or of its branches. But at certain epochs lateral structures are developed at the sides of the filaments, as branch cells, which become shut off from the main tube by septa; some of these processes expand into ovate and beaked or bird's-head-shaped bodies, others into short curled filaments or "horns." The former are *sporanges*, the latter *antheridia*. When ripe, the *antheridia* or "horns" discharge their cell-contents in the form of numerous spindle-shaped corpuscles, moving actively by the help of a pair of cilia. Meanwhile an orifice i formed in the beak of the sporange, and some of the spermatozoid

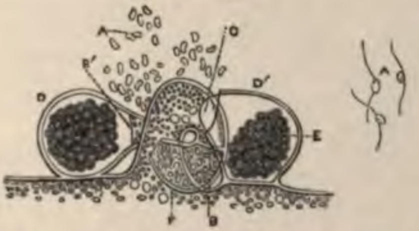
Fig. 539.



*Œdogonium ciliatum*: A, ordi
nary cells, in each of whic
a zoospore (E) is formed
C, C, sporangia; B, B, an
drospores, one bearing at
an antheridium, the lid o
which is detached; D, ex
tremity of the plant.

make their way in, so as to come into direct contact with the cell-contents. This phenomenon is followed by the closing-up of the sporange by a membrane, and the conversion of its contents into a fertile *resting-spore*.

Fig. 540.



*Vaucheria*: A, A, spermatozoids; B, C, horn-like antheridium; D, D', sporanges; E, spore.

830. *Sphæroplea* is another genus of filamentous Confervoids, composed of rows of cylindrical cells, in which fertilization of the resting-spores by spermatozoids has been directly observed (Cohn). In some of its cells the contents are converted into a number of globular bodies, in others the contents are developed into numerous spermatozoids. When mature, orifices are formed in walls of the cells of both kinds; the spermatozoids escape from their parent cell, and make their way in through the orifices of the parent cells of the spores; the latter when fertilized produce their cellulose coat, and ripen to resting-spores, which are set free by the decay of the parent filaments.

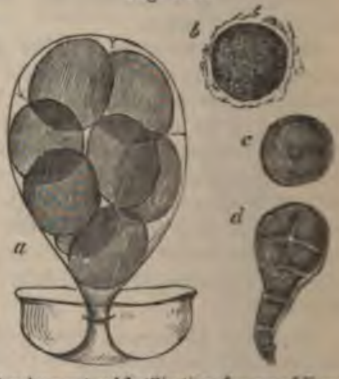
Analogous phenomena have been recently observed in various other filamentous Confervoids, as in *Œdogonium*, *Bulbochæte*; and Cohn has lately described a similar process in *Volvox*.

831. The mode of fertilization in the Florideæ (§ 546) or Red Sea-weeds, has been well made out by MM. Thuret and Bornet, who thus describe the process in *Helminthora*. A small cell, originating on the side of one of the dichotomous filaments of which the frond is composed, elongates, divides transversely, and becomes a short branchlet made up of four superposed cells, of which the uppermost alone continues to develope. Shortly there may be seen projecting from the summit of this uppermost division a little protuberance, which gradually lengthens into a long hyaline hair, often dilated at the extremity. This is the *trichogyne* or essential organ of fertilization. When the spermatozoids (here globular and motionless) come into contact with the upper part of this hair they adhere to it. Then the cell which forms the base of the trichogyne swells and divides

into segments, and is soon transformed into a small cellular mass, which gradually forms the young "cystocarp" or mass of spores. The trichogyne gradually disappears. In *Callithamnion* the aggregations of spores called *favellæ* (§ 546) are formed from the side, not at the base, of the trichogyne, in consequence of fecundation by the antherozoid. Here, then, we have motionless antherozoids formed in the antheridium of one plant, escaping and coming into contact with the free end or style-like process of another plant; and as a result of this contact, the cell at the base divides and subdivides into a mass of spores.

832. The observations made by Thuret on Fucaceæ are very decisive. In this Order the *conceptacles* (§ 547) produce in their interior bodies of two kinds, *antheridia* (fig. 464, *c*) and *spore-sacs* (fig. 464, *e*), either together or in separate conceptacles (monœcious), or in separate plants. The antheridia discharge 2-ciliated *spermatozoids* (fig. 464, *d*), which are poured out through the pores of the *receptacles* (fig. 464, *a*) into the surrounding water. At the same time the spore-sac (fig. 464, *e*) bursts and emits an inner sac (fig. 541, *a*), in which may be observed 2, 4, or 8 (*a*) spherical corpuscles, destitute of a cellulose membrane; this inner sac breaking loose, bursts and discharges its corpuscles, which, like the spermatozoids, pass through the pores of the receptacle into the water. Here they become surrounded by a cloud of spermatozoids (fig. 541, *b*) which attach themselves to the surface, and by their ciliary movement cause the spheres to revolve. In the course of a few minutes, usually, a cellulose membrane is formed upon the surface of the globular corpuscle (by secretion from its primordial utricle?), and it becomes a cell (fig. 541, *c*), which subsequently germinates, growing by cell-division (fig. 541, *d*) into a new frond.

Fig. 541.



Development and fertilization of spores of *Fucus vesiculosus*: *a*, inner spore-sac bursting from the outer sac and about to liberate the spores; *b*, a free spore (devoid of cellulose coat) surrounded by spermatozoids; *c*, impregnated spore with a cellulose coat; *d*, the same germinating. Magn. 160 diameters.

These observations upon the fertilization of the germinal corpuscles of the Algæ are of extreme interest, both as offering examples of the process of sexual conjunction of the simplest kind in plants, and as affording, like the development of zoospores (§ 698), beautiful illustrations of the theory of free-cell formation (§ 697) by the production of a cellulose coat around a naked primordial utricle after it has been completely separated from the parent,—a phenomenon never met with in the higher plants, where this kind of cell-formation can only be observed in the interior of the parent structures, as in the embryo-sac of the Phanerogamia.

833. In the conjugating Algæ we observe the new cell to be produced by the complete union of the entire contents of the spore-cell and germ-cell, which are undistinguishable from each other. In the other kinds cited, the contents of the germ-cell become converted into one or more globular corpuscles, rudimentary spores; while the contents of the sperm-cells are developed into numerous minute corpuscles, usually of a spindle-shape (not spiral), moving actively by a pair (?) of cilia. The corpuscles of the germ-cells acquire a cellulose coat and become cells; the spermatic corpuscles disappear after they come into contact with the nascent spores, either dissolving or becoming absorbed into the substance of the latter.

## Sect. 4. Reproduction of Angiosporæ, or Leafy Cryptogamia.

834. The reproduction of the Orders included in this division presents but one common character, namely the representation of the sperm-cell by antheridial cells, whose contents are discharged in the form of spirally coiled filaments moving actively in the water by means of two or more ciliary appendages. In the majority of the Orders the female organ occurs in a form somewhat analogous to the ovule of Phanerogamia, called the *archegonium* (or *pistillidium*), which gives rise, however, to very different products in the different groups. In the Characeæ there is no distinct *archegonium*, the spore being directly fertilized and growing up into a new plant; yet as this spore presents the external characters of an *archegonium*, and the *antheridia* are spiral, the Order is clearly referable to the present division.

In the Gymnosporæ the fertilization of the germ-corpuscle is followed by its conversion into a spore (*Spirogyra*, *Vaucheria*), or into a cell which may be called a *sporangial cell* on account of its contents undergoing division into a number of new germs when it begins to grow (*Closterium*, *Bulbochæte*, &c.). In the Angiosporæ (excepting Characeæ) the relations of the spores to the proper sexual structures are more distant and very diverse, the course of development being much more complicated.

### *Characeæ.*

835. The reproductive organs of this Family are very distinctly characterized, and borne in a conspicuous external position. The two kinds, male and female, called respectively the *globule* and the *nucule*,

occur either together on the same branch of the plant, on distinct branches, or on separate plants.

836. The *globule*, or *antheridium*, is a spherical case composed of eight (triangular) segmental pieces, each of which is formed of a number of cells radiating from a central one; all these have red or orange contents, imparting a colour to the *globule* as seen in its natural condition. From the central cell of each valve projects inward an oblong cell; these eight cells meet in the centre together with the apex of a flask-shaped cell which enters the globule at its base, forming the pedicle by which it is attached to the branch. Where these nine cells meet in the centre is found a little cellular mass, from which arise a number of slender jointed filaments. When the globule is mature, its valves separate, and each carries away its central cell bearing a tuft of the jointed filaments. The cells forming the joints of these filaments are then seen each to contain a minute spirally coiled thread, which makes its way out and appears as a 2-ciliated actively moving *spermatozoid*, resembling those of the Mosses.

837. The *nucule* is a somewhat anomalous organ, presenting at first the characters of an archegonium, and afterwards those of a spore. It consists essentially of a large oval cell surrounded by a double coat and, outside this, by five spirally coiled and intimately connected cortical filaments. The five spiral cells terminate at the summit in five (or ten) teeth; and it appears that these teeth separate from each other at a certain epoch, leaving a free passage down the centre, to the wall of the central cell. In this state we may compare the structure to an *archegonium*, or to an *ovule* of Phanerogamia. It is supposed that spermatozoids from the globule pass into the canal between the crown of teeth of the nucule and cause it to become fertile. The product, however, of the fertilized central cell is not a free embryo or a spore, but it becomes itself the first cell of the new plant, like a spore. After fertilization the nucule drops off from the parent, passes through a stage of rest, and in the following season germinates like a seed or spore and grows up at once into a new plant. Pringsheim, however, states that the spore developes a true prothallus like that of the Mosses.

In favour of the supposition that the young nucules are impregnated while the apical crown of teeth is open, we have two circumstances, namely:—that the spermatozoids are discharged from the globules at the same period; and, secondly, that when the nucules are ripened in autumn, they germinate in the following spring, at an epoch when no spermatozoids are in existence.

## *Axogamia.*

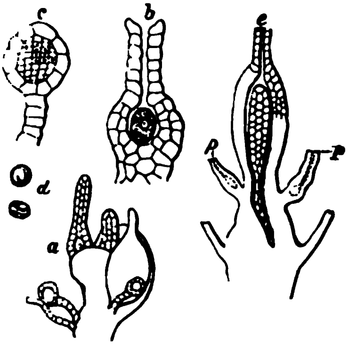
838. Under this title we include the Liverworts and Mosses, on account of their sexual organs, essentially similar in kind and mode of development, being in all cases developed upon the axis of the perfect leafy plant.

Both Liverworts and Mosses produce *antheridia* and *archegonia*, either on the same plant or on distinct individuals. There are minor differences of structure in the different groups of these Orders, some of which may be briefly described.

839. The *antheridia* of the Hepaticæ (and with these agree the same organs of Sphagnaceæ) are elliptical or globular sacs (fig. 542, *c*) formed of a single layer of cells; they are found imbedded in the thalloid stem of *Riccia*, *Pellia*, &c., or in the substance of the (male) receptacles of *Marchantia* (p. 425), or on stalks arising from the frondose stem, in *Fossombronia*, and in the axils of the leaves in the foliaceous kinds of *Jungermannieæ* (fig. 542, *a*). The interior of the sac is filled with minute roundish cells, at first coherent, but ultimately free. These (the *sperm-cells*) escape by the rupture of the sac of the *antheridium*, and each of them emits a 2-ciliated spiral spermatozoid (fig. 542, *d*).

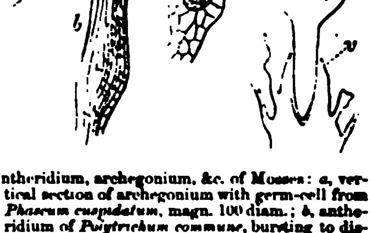
840. In the Mosses the *antheridia* are larger and more elongated and cylindrical sacs, not stalked (fig. 543, *b*); they are found in the axils of leaves, sometimes scattered, but more frequently collected in axillary

Fig. 542.



Antheridia and archegonia &c. of Hepaticæ: *a*, vertical section of the inflorescence of *Radula complanata*, with young (axillary) antheridia and (terminal) archegonia, magn. 50 diam.; *b*, vertical section of an archegonium, with germ-corpuscle, of *Jungermannia divaricata*, magn. 250 diam.; *c*, immature antheridium of *Radula complanata* (vert. section), magn. 250 diam.; *d*, Spermatozoid; *e*, immature fruit, with surrounding epigone and two abortive archegonia (*p p*) of *Radula complanata* (vert. section), magn. 100 diam.

Fig. 543.



Antheridium, archegonium, &c. of Mosses: *a*, vertical section of archegonium with germ-cell from *Phascum cuspidatum*, magn. 100 diam.; *b*, antheridium of *Polytrichum commune*, bursting to discharge spermatozoids, magn. 25 diam.; *c*, sperm-cell and spermatozoid of the same, magn. 200 diam.; *d*, spermatozoids of the same, magn. 400 diam.; *e*, immature fruit of *Phascum bryoides* (vertical section), *c*, calyptra, *v*, vaginule, magn. 40 diam.

or terminal bud-like structures (*inflorescence*), either with the archegonia, or in a monœcious or diœcious condition. The antheridial sacs are filled with a tissue which is ultimately resolved into *sperm-cells*, which are discharged by the bursting of the sac (fig. 543, *b*); and when these escape (fig. 543, *c*) they in their turn emit an active, spirally twisted, 2-ciliated *spermatozoid* (*d*).

The *antheridia* and *spermatozoids* of Mosses may be readily observed in *Polytrichum commune*, the male plants of which form their "flowers" (*stellulæ masculinæ*) abundantly on every heath in spring.

841. The *archegonia* are very much alike in Hepaticæ and Musci, being flask-shaped cellular cases, with a long neck (fig. 542, *a*, *b*; fig. 543, *a*), found generally several together, commonly at the ends of shoots, surrounded by modified leaves, which receive special names (pp. 421, 423), forming a kind of perianth. In *Anthoceros* the archegonium is formed in the substance of the thalloid stem. When mature, the archegonia exhibit in their basal cavity a *germ-corpuscle* (fig. 542, *b*; fig. 543, *a*), which in all probability is fertilized by the passage of spermatozoids down the canal of the neck of the flask-shaped body. In any case this corpuscle is converted into a cell in one of the archegonia of a flower, the rest remaining barren (fig. 542, *p*, *p*).

Hofmeister has observed spermatozoids actually within the canal of the *archegonium*, in *Funaria hygrometrica*. M. Lortet has not only assured himself that these active spiral corpuscles descend by the neck of the archegone until they reach the central cell, but he states that he has witnessed the manner in which the latter is fertilized by the moving spirals. Fecundation is effected by the contact of a certain little vesicle which the spermatozoids carry at the side of their swollen extremity, which vesicle contains some six or eight amylaceous corpuscles, and increases very much in size at the moment the process is accomplished. M. Lortet has repeated, in the vegetable kingdom, the experiment formerly made by MM. Dumas and Prévost with certain animals. He submitted the fertilizing liquid of the *Preissia commutata*, containing the antherozoids, to filtration, and found that the thick juice which passed through the filter was incapable of rendering the plant fruitful, whilst the matters retained by the filter, which swarmed with spermatozoids, rendered all the archegones fertile; this was proved by applying the contents of the filter, by means of a soft brush, over the female organs. M. Lortet has, moreover, remarked that the cilia of the spermatozoids terminate, like the antennæ of several insects, in a little expansion or swelling.

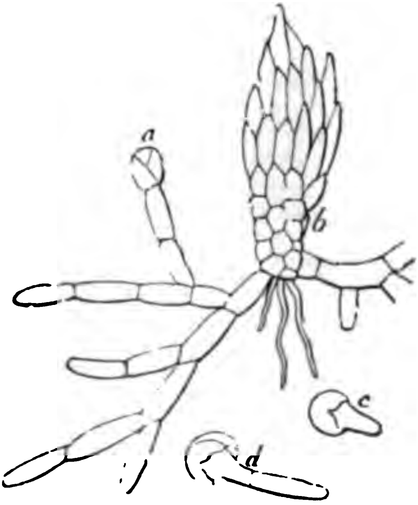
842. When the germinal cell is fertilized, it begins to grow by cell-division, and forms a cellular body which causes the expansion of the original wall of the *archegonium* (fig. 542, *c*). After a time, this wall gives way, in the Mosses by a circumscissile dehiscence, so that the upper part is carried upwards (fig. 543, *e*, *c*), afterwards becoming the *calyptra* (p. 421), while the lower part (fig. 543, *e*, *v*) remains as

the *vaginule* (fig. 459, *c*). In the Hepaticæ the sac of the archegonium is usually ruptured in the upper part, and there is no cup-shaped calyptra formed, the sac becoming ultimately the envelope, corresponding to the vaginule of Mosses, here often called the *epigone* (p. 424, fig. 460, B, *a*).

The central cellular body (fig. 542, *e*) undergoes very remarkable changes: by degrees it exhibits different strata and regions, and in the most perfect forms of this Class ultimately rises out on a stalk-like process from the vaginule (fig. 543, *v*), and becomes a *sporangium* or *capsule*, filled with spores (pp. 420–425).

The mode of development of the spores, which are simple cells with a double coat, or a proper cell-membrane covered by a distinct *cuticular* (§ 638) layer, is briefly as follows:—In the cellular rudiment of the capsule, concentric layers of the parenchyma become differently metamorphosed: the outer layers form the walls of the capsule and the sporangial membrane below, continuous with the *peristome* (p. 421) above; the central mass (in Mosses) is developed into the columella: the intermediate layers, which produce the spores, after multiplying to a certain extent, form free cells from the whole contents of each cell; the walls of the original or parent cells dissolve, and a cavity is formed, in which the free cells (parent cells of the spores) lie loose. These cells become divided into four chambers by septa; and each of these chambers (special parent cells of

Fig. 544.



Germination of the spores of a Moss (*Funaria hygrometrica*): *c*, spore sprouting; *d*, more advanced, and the first cell divided; *a* and *b*, nascent leaf-buds on the confervoid protonema. Magn. 200 diam.

the spores) produces a single free cell from its whole contents. The last-formed cells, set free by the solution of their mother cells, are the spore-cells, which when ripe are found coated with a cuticular layer, often more or less marked with points or reticulations, like pollen-grains.

In the subsequent history, another kind of propagation takes place. When the spores germinate, they produce a confervoid structure (*protonema*, fig. 544), from different cells of which are produced a number of buds (*a*, *b*), each of which grows up into a new leafy stem, forming a tufted group of plants, which after a time fructify again by *antheridia* and *archegonia*.

## *Thallogamia.*

843. In this group of Flowerless plants we meet with a curious displacement of the reproductive structures, which do not occur in immediate connexion with the morphologically perfect plant, but on a temporary structure produced by and cast off by the leafy stem.

Ferns and Equisetaceæ, unlike as they are in their complete forms, agree so closely in their sexual reproduction, that, like the Liverworts and Mosses, they may be described together. Both these groups are characterized by producing but one kind of spore, developed in sporanges, more or less intimately connected with the foliaceous structure (pp. 414, 417). When these spores are sown, they germinate by emitting a tubular process (fig. 545, *a*), which by cell-division (*b*) enlarges into a small, green, leaf-like plate, somewhat like the frond of a Liverwort, called the *prothallium* (*c*). This is capable of supporting itself, having filamentous rootlets; and if the changes next to be described do not immediately take place, this *prothallium* often propagates vegetatively, new *prothallia* budding out from its base.

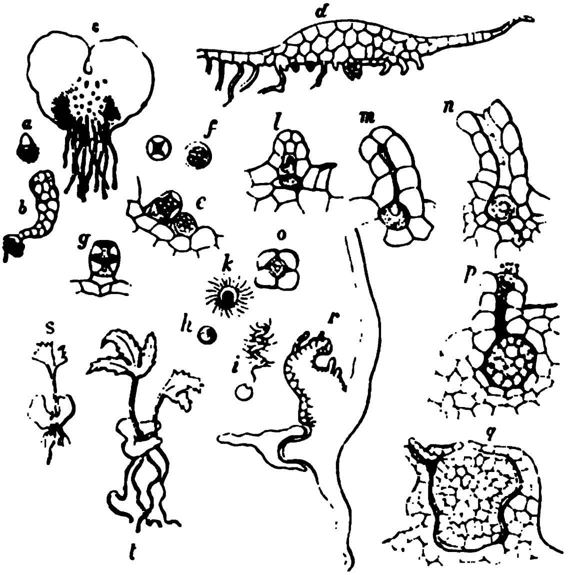
When completely formed (*c*), this structure exhibits on its under surface cellular papillary bodies of two kinds, which are the *antheridia* and *archegonia*: the former are scattered over the whole surface; the latter, less numerous, are chiefly found in the thickened central region, from which the rootlets arise, especially between this and the anterior notch.

844. The *antheridia* are structures composed of one cell (or two superposed), developed from the lower free face of one of the cells of the prothallium (fig. 545, *e*, *f*). In the interior a second cell is formed, the contents of which become segmented and developed into a number of minute vesicles, the *sperm-cells*. When ripe, the top of the antheridial cell falls off like a lid and the sperm-cells escape (*h*); each of these emits a *spermatozoid* (*i*, *k*), differing in form from that of the Mosses and Liverworts, and having numerous cilia. The spermatozoids are, moreover, provided with a mucilaginous vesicle, which is supposed to be of consequence in the process of fertilization.

845. The *archegonia* are developed on the same *prothallium* as the

*antheridia* in many Ferns; the Horse-tails appear to be diœcious, *archegonia* having been detected only on distinct *prothallia.* The external structure is a papilla formed of four collateral tiers of cells, with a canal running down the central intercellular passage (fig. 545, *l*, *m*, *n*, *o*). The papilla projects from the lower surface of the prothallium; and when mature its canal has an open mouth (*n*). The canal leads to a basal cell (*embryo-sac*), in which lies a germinal corpuscle (*n*), as in the *archegonium* of Mosses (§ 841). This corpuscle is fertilized by the entrance of spermatozoids into the canal, and becomes the embryonal cell. Seldom more than one archegonium in a prothallium becomes fertile; the abortive ones acquire a peculiar brown colour in the canal and embryo-sac.

Fig. 545.



Reproduction of Ferns: *a*, spore germinating; *b*, more advanced (magn. 50 diam.); *c*, full-grown prothallium, with archegonia (lower surface); *d*, vertical section of the central region of a prothallium, passing through an archegonium and two antheridia; *e*, two antheridia (side view); *f*, antheridia seen from above; *g*, antheridium burst (side view); *h*, sperm-cell from antheridium; *i*, spermatozoid escaping from sperm-cell (magn. 300 diam.); *k*, front view of a spermatozoid; *l*, vertical section of a young archegonium; *m*, more advanced; *n*, still older, with the canal open, and an embryonal corpuscle in the sac (magn. 100 diam.); *o*, view of the mouth of an archegonium, from above; *p*, vertical section of an archegonium with the embryo in course of development in the sac; *q*, the same, more advanced (less magnified); *r*, vertical section of young plant, more advanced, with a fragment of the prothallium (magn. 50 diam.); *s*, *t*, young plants of *Pteris serrulata*, with their first and second leaves and adventitious roots, still connected with their prothallia.

Cell-division ensues in the *embryo* thus formed (fig. 545, *p, q*); but the result is not the formation of a capsule, as in the Mosses, but of a bud, producing leaves (*r*) gradually more and more perfect (*s, t*) in the Ferns, and of the characteristic stem in the Equisetaceæ. When these vegetative structures are sufficiently mature, they produce the sporanges and spores, as described in a former section (p. 418).

The development of the spores of Ferns is similar in its most essential points to that of the Mosses. The thecæ or sporanges (p. 418) are produced from certain cells of the parenchyma of the fertile leaves; and when mature, they break out upon the lower surface, naked or covered by the indusia (p. 418). They are at first cellular papillæ, the parenchyma of which becomes differentiated in the course of development; the outer layer forms the cellular wall of the sporange and the *annulus* (p. 418), while the central parenchyma assumes the character of parent cells of the spore-cells, which are developed in fours, as in Mosses &c., and acquire when ripe a cuticle marked with granules, spines, or ridges (fig. 458, *p*).

### *Sporogamia.*

846. It has long been known that the Lycopodiaceæ and the Marsileaceæ produce spores of different kinds, unlike especially in size, so that they are conveniently distinguished as *microspores* and *megaspores*. These are produced in similar or only slightly different sporanges (pp. 411–414), which in the Marsileaceæ occur together or separately in an additional envelope, forming the spore-fruit (p. 411).

The reproduction by means of these spores presents characters greatly differing from those described in the preceding group, and approaching those found in the Phanerogamia.

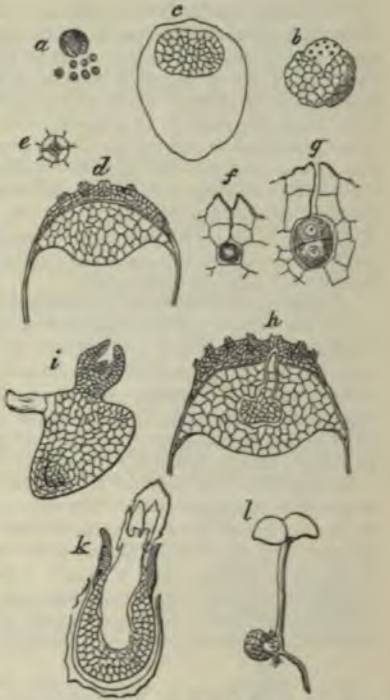
847. When the *microspores* of Lycopodiaceæ and *Pilularia* are sown, their contents are converted into minute *sperm-cells*, discharged when mature, and each giving birth to a ciliated *spermatozoid* (fig. 546, *a*). In *Salvinia*, the microspores produce cellules, each of which produces again several sperm-cells in its interior.

The formation of the microspores, in their capsules, agrees essentially with the development of the spores of Ferns in their thecæ.

848. The *megaspores* have a very different history, subject to slight modification in particular genera; it will suffice to describe as an example the mode of development in *Selaginella*.

When the large spore of *Selaginella* is sown, after some time the outer tough coat bursts at the apex, marked by the convergence of three ridges externally (fig. 546, *b*); when this opening of the outer coat takes place, it is found that a discoid layer of minute cells has been developed, between a second coat lining the cuticular layer and a third coat, which immediately encloses the fluid contents of the spore; this coat may be extracted from the outer coat, and the cellular disk is then seen upon its upper end (fig. 546, *c*). This disk is the *prothallium*, and upon its exposed surface (*b*) are found the *archegonia* (in *Selaginella* numerous, in *Pilularia* &c. solitary). Cellular tissue is also developed in the large sac of the spore, underneath the disk, but separated from it by the inner spore-coat. This is shown in the vertical section of the spore (*d*). The archegonia consist of an embryo-sac, with an intercellular canal leading down to it (*f*), the four upper cells bordering the canal being more or less produced above the surface of the prothallium (*d*, *f*). In the embryo-sac lies a *germinal corpuscle* (*f*), which is doubtless fertilized by the spermatozoids of the microspores, but at what time and in what manner is as yet not known.

Fig. 546.



Reproduction of *Selaginella* (Lycopodiaceæ): *a*, small or antheridial spore discharging sperm-cells, containing spermatozoids (magn. 100 diam.); *b*, large spore, with the outer coat bursting, to display the prothallium bearing archegonia (magn. 15 diam.); *c*, large spore with the outer coat removed, showing the entire inner coat, with the cellular prothallium at the upper end (magn. 100 diam.); *d*, vertical section of a more advanced prothallium with archegonia (magn. 100 diam.); *e*, *f*, *g*, archegonia with embryonal corpuscles in the sacs (magn. 500 diam.); *h*, vertical section of prothallium, with the embryo developed from one archegonium imbedded in the cellular mass of the spore-sac (magn. 100 diam.); *i*, more advanced embryo, extracted from the spore, with its suspensor (magn. 100 diam.); *k*, vertical section of a spore, with embryo breaking forth (magn. 15 diam.); *l*, young plant, with stem, leaves, and root, still connected with the spore from which it has emerged (magn. 2 diam.).

849. The fertilized germinal corpuscle is then developed by cell-division, forming the *embryo*, which in *Selaginella* descends into the cellular tissue of the large cavity of the spore (fig. 546, *h*), its primary cells growing into a filamentous *suspensor*, bearing the true embryo-cell at the lower end. The embryo (fig. 546, *i*) gradually takes form and produces a leaf-bud (*k*), and sends out an adventitious root; the bud and the root escape from the spore-coat (*l*), leaving behind the cellular mass (pseudo-

cotyledon?) first formed, which dies away as the stem grows, like the cotyledons of a germinating Pea.

The young plant (*l*) thus formed grows up at once into a new leafy stem, ultimately forming sporanges &c.

The conditions in *Isoëtes*, and also in *Pilularia* and other Marsileaceæ, differ in various points—such as the absence of a suspensor in *Isoëtes*, the existence of only one archegonium in the Marsileaceæ &c. Seldom more than one of the archegonia become fertile in Lycopodiaceæ. The development of the embryo of the genus *Lycopodium*, in which only *microspores* have been observed, is at present involved in obscurity, no attempts to cause germination having as yet succeeded. Spring, the monographer of this group, even goes so far as to express the opinion that the genus *Lycopodium* was originally diœcious, and that one of the sexes has been lost, so that the male plants alone remain, perpetuated by simple vegetative division. This view, however, is improbable. The male plant would probably, as in other cases, occasionally produce female organs; but these have as yet escaped observation.

A peculiar phenomenon is exhibited in the formation of the *megaspores* of these Orders. The microspores are developed in fours in parent cells, much as in Ferns and Mosses as regards the metamorphosis of the internal parenchyma of the sporanges into free cells. But in the development of the megaspores, when the parent cells of the spores are formed, in *Selaginella*, all of them but one in each sporange are abortive, the single remaining one forming four special parent cells, and, ultimately, four large spores which fill the sporange.

In *Pilularia* not only do all the parent cells but one disappear in the megaspore-sporanges, but, when this one divides into four special parent cells, only one of the spore-cells continues to be developed, the other three disappearing, so that the female sacs contained in the spore-fruits of *Pilularia* each enclose only a single *megaspore*. This megaspore departs greatly in external character from all the other structures described as spores in the leafy Cryptogams, and approaches in some degree the character of a detached ovule of a Flowering plant.

## Sect. 5. REPRODUCTION OF PHANEROGAMIA.

850. The remarkable distinguishing character of this group of plants is the possession of *stamens* producing *pollen*, and of *carpels* producing *ovules*, the latter of which are matured, while still nourished by the parent organism, into *seeds* containing an *embryo* (§§ 16 & 300)—a rudiment of the future plant, in which the vegetative organs, stem, leaf, and root, can in most cases be distinguished.

The formation of these reproductive organs closes the life, or, in perennial plants, the periodical cycle of growth; and the progeny thrown off, after passing through a stage of rest, germinate directly into a new, perfect morphological representative of the species.

851. In the Flowering Plants, as indicated in the preceding Parts of this work, there are some important differences in the construction of the essential organs of the flowers, accompanied by a

striking variation in the course of development of the embryo subsequent to the concurrence of the sperm-cell with the original germ-cell of the ovule. The Morphological differences of the Gymnospermia and Angiospermia have been indicated already; in describing the minute phenomena occurring in their sexual reproduction, it is advisable to treat them separately; but as the *pollen-grains* are produced on the same plan in both groups, these structures may be previously disposed of in a brief account of their general history.

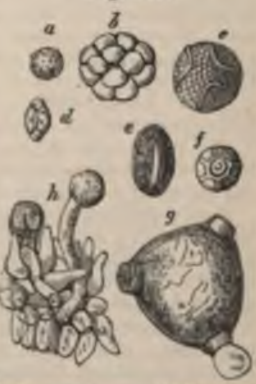
### *Pollen-grains of Phanerogamia.*

852. Pollen-grains, the sperm-cells of Phanerogamia, differ importantly from the sperm-cells of the Leafy Cryptogamia in the absence of any corpuscular contents analogous to spermatozoids; their protoplasm exhibits simply a nucleus, with granules of starch, oily matters, and other ordinary cell-contents (§§ 595, 596). In this respect they approach the fertile cells of Conjugating Algæ (§ 827).

853. In their simplest forms they are single cells, with a proper cell-coat and an outer cuticular coat, mostly marked with irregularities, forming a kind of pattern on the surface, sometimes very elegant. In particular cases the outer coat is laminated, so that the pollen-cell appears to have several coats. In all cases the outer coat exhibits one, three, or many round holes or slits (*pores*) (fig. 547, *e*), where the inner coat is bare; in the pollen of *Passiflora*, *Cucurbita*, &c. there exist lid-like covers over the pores (fig. 547, *c*).

854. The form and size of pollen-grains vary very much, as may be observed even in the few examples here figured; but although there may be a general resemblance throughout particular genera, and even Orders, they do not often afford good or regular systematic characters. The most frequent cases of agreement in allied plants occur when they possess *compound* pollen-grains (fig. 547, *b*, *d*), consisting of a number of pollen-cells permanently coherent together. The most striking cases of this are those offered so abundantly in Orchidaceæ (§ 509) and Asclepiadaceæ (§ 458), as to form valuable systematic characters in these Orders. These *pollen-masses* or *pollinia* consist either of the entire mass of pollen

Fig. 547.



Pollen-grains, magn. 100 diameters: *a*, *Bellis*; *b*, *Acacia laxa* (compound grain); *c*, *Passiflora cærulea*; *d*, *Periploca græca*; *e*, *Tradescantia*; *f*, *Cichorium Intybus*; *g*, *Epilobium montanum*; *h*, *Lathræa Squamaria*, forming pollen-tubes among the cells of the stigma.

of an anther-cell, or of a half, quarter, eighth, or smaller fraction, so numerous in some genera as to appear like granules merely coarser than ordinary pulverulent pollen.

The existence of pollen-masses and compound grains is readily accounted for by the history of the development of pollen, which agrees in the main points with that of the spores of Mosses &c. (§ 842). The parenchyma in the central region of each lobe of a young anther presents two perpendicular rows of cells, one corresponding to each of the four primary loculi (§ 206), different in character from those which are to form the walls. The cells in these series multiply by division to a considerable extent; and ultimately each forms a free cell from its whole contents—the parent cells of the pollen. These are set free by solution of the walls of the parenchymatous framework in which they have been developed, and they then lie as loose cells in the loculi or chambers of the anther thus formed. Each parent cell divides into four chambers; and each of these chambers (special parent cells) produces a pollen-cell, in the case of simple pollen-grains set free by the solution of the special parent cell. In quaternary pollen (fig. 547, *d*) the membranes of the special parent cells are not dissolved, and thus the pollen-cells are held together in fours; and the more complex conditions arise from the membranes of the parent cells of anterior stages persisting sufficiently to hold their progeny together. The mode of formation of the pollen in the special parent cells is by some attributed to cell-division; but the more generally adopted view is that it is formed by free-cell formation. The nucleus of the parent cell divides into two; between these two a quantity of granules of protoplasm are aggregated together in a direction across the parent cell; these granules are suddenly seen to be divided by a line, the first indication of the cell-wall between the two cells so produced; these two again subdivide; and thus four pollen-cells are ultimately found in one parent cell. The pollen-masses of the Asclepiadaceæ, and perhaps of some Orchidaceæ, result from a different process: in these the outer layers of the primary parent cells do not develope cells in their interior, but become conjoined into a cellular pellicle forming a sac or purse enclosing all the pollen-grains formed within.

The pollen-cells acquire their cuticular coat after they have become free; but part of the material of this structure appears to be derived from the dissolved membranes of the parent cells.

*Zostera* presents a remarkable exception to the usual character of pollen-grains, the cells here having the form of short cylindrical filaments with but one coat, *i. e.* without a cuticular layer. In these a rotation (§ 736) of the cell-contents may be observed, which is likewise occasionally to be seen in recently formed pollen-tubes of other plants. The minute starch-grains of the cell-contents are noticeable as exhibiting a molecular motion, which was at one time imagined to be of vital character, and might lead the inexperienced to suspect the existence of minute spermatozoids.

### *Pollen-grains of Gymnospermia.*

855. The pollen-grains of the Gymnospermia present a modification of the structure above described. They are not simple cells, but produce in their cavity, even before they are discharged from the an-

ther, minute cellular bodies, composed of two or four cells, adherent to that side of the pollen-grain where the *slit* (§ 853) exists in the outer membrane.

856. In the Phanerogamia, when a pollen-grain falls upon a *stigma* in its proper or "receptive" state (known by the presence of a saccharine secretion), the inner coat is protruded in the form of a blind pouch (fig. 547, *h*) from one or more of the pores or slits, and, nourished by the stigmatic secretions, grows into a filament of great tenuity, which makes its way through the loose stigmatic cells, and passes down the canal of the style into the cavity of the ovary, there following the course of the placentas when the ovules are numerous.

857. In the Gymnospermia the pollen-grains fall at once upon the ovules and pass into the micropyle, sending down their pollen-tubes—here developed from the internal cellular body (§ 855), which penetrates through the proper coat of the pollen-cell—into the substance of the nucleus of the ovule, towards the deep-seated embryo-sac.

The formation of imperfect pollen-tubes may sometimes be caused by placing pollen-grains in syrupy fluids; but when they are placed in dilute sulphuric acid &c. the extrusion of the inner coat which results is mostly a process of mechanical expansion, and the projecting pouches soon burst and discharge the contents of the cell, owing to endosmotic action.

### *Ovules of Phanerogamia.*

858. The ovules of Phanerogamia are all constructed according to some modification of one general plan. The essential part is the *nucleus* (fig. 548, *a*) or principal cellular mass, in the interior of

Fig. 548.

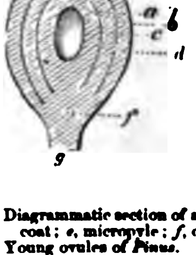


Fig. 549.

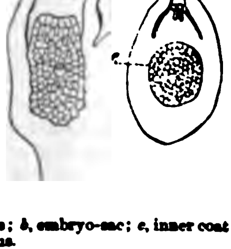


Fig. 548. Diagrammatic section of an ovule: *a*, nucleus; *b*, embryo-sac; *c*, inner coat; *d*, outer coat; *e*, micropyle; *f*, chalaza; *g*, funiculus.

Fig. 549. Young ovules of *Pinus*. A. Vertical section at the time when the primary embryo-sac is a small cell in the centre of the nucleus: *m*, micropyle. B. Section of an older ovule: *m*, micropyle with two pollen-grains on the apex of the nucleus; *e*, the primary embryo-sac filled with cellular tissue. Magn. 50 diam.

which one of the cells is greatly enlarged, forming a more or less considerable cavity (fig. 548, *b*), the *embryo-sac*. The nucleus is attached to the placenta of the carpel to which it belongs by the *funiculus* (*g*) or *podosperm*. In most cases one or two coats exist, covering up the nucleus, forming the *internal* (*c*) and *external* (*d*) *integuments*. These do not quite meet at the apex, but leave an orifice, the *micropyle* (*e*), leading to the point of the nucleus. The region where the base of the nucleus is continuous with the coats (*f*) is called the *chalaza*, the position of which, in reference to the funiculus and micropyle, varies in different forms of the ovule (§§ 236–240).

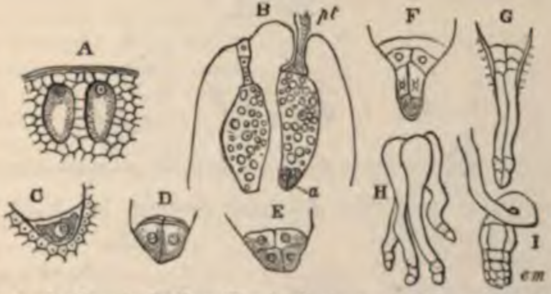
### *Ovules of Gymnospermia.*

859. The ovules of the Gymnospermia, Pinaceæ and their allies, and Cycadaceæ, are produced upon open carpels, so that the pollen-grains have direct access to the micropyle (fig. 551, A, *a*). In *Pinus* two of these occur at the base of the carpellary scale. Each consists of a nucleus, with only a single integument (549, A). In this first figure the primary embryo-sac is represented in the centre as still very small. Before the pollen-grains fall on the micropyle of the ovule, the embryo-sac becomes filled up with delicate cellular tissue (endosperm-cells). Fig. 549, B, represents a section of an ovule with the embryo-sac (*e*) filled up in this way, and two pollen-grains which have penetrated into the micropyle (*m*) pushing their pollen-tubes into the substance of the nucleus.

In the upper part of the mass of endosperm (*e*), from five to eight cells are found to expand more than the rest, forming *secondary embryo-sacs*. These are not formed in the superficial cells of *e*, but from cells of the second layer, so that each is separated from the membrane of the primary embryo-sac by one cell (fig. 550, A). Those cells lying between the *secondary embryo-sacs* and the surface of the endosperm next undergo division crosswise, so as to form a rosette of four cells, which separate at the converging angles, and leave a central intercellular passage down to the secondary embryo-sac. In this state, these *corpuscula*, as they were called by R. Brown, their discoverer, are very much like the *archegonia* in the internal prothallium-structure of *Selaginella* (§ 848).

The pollen-tubes travel down through the substance of the upper part of the nucleus, and reach the mouths of the canals of the *corpuscula*, one entering each (fig. 550, B, *p t*). At the same time *germinal corpuscles* are produced at the base of the secondary embryo-sacs (fig. 550, B, *a*). These, after fertilization, by the contact of the pollen-tube with the upper end of the sac (*p t*), become cells, multiply and form a cellular mass (C, D, E), the lower cells of which break out through the bottom of the endosperm, and grow as four cellular filaments (F, G, H) into the substance of the lower part of the nucleus of the ovule. At the ends of these filaments cell-division again occurs (I); and from the apex of one of these *suspensors* (§ 849) is developed the embryo (I, *em*). As there are several corpuscles, and each produces four suspensors, a large number of rudimentary embryos are developed; but usually only one of all these rudiments is perfected.

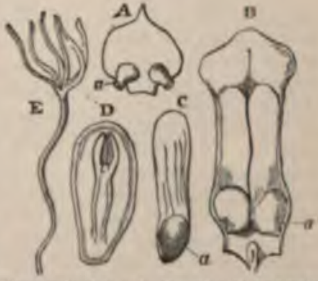
Fig. 550.



Development of embryo in Coniferæ (*Pinus*): A, upper part of the embryo-sac, with two *corpuscula* or archegonia; B, the same more advanced, the right-hand one with a pollen-tube (*p t*) in its canal and germinal corpuscles (*a*) at the base; C, D, E, successive stages of development of *a* in B; F, G, H, development of these cells into suspensors, at the end of one of which the embryo is produced, shown in I (*em*). Magn. 100 diam.

That embryo which is fully developed gradually increases in size, and most of the structures above described disappear, so that the ripe seed exhibits a single embryo imbedded in a mass of endosperm or albumen (fig. 551, D), the latter originating apparently from the nucleus of the ovule. The radicle is covered by a *pileorhiza* (§ 680), which is intimately blended with the substance of the endosperm.

Fig. 551.



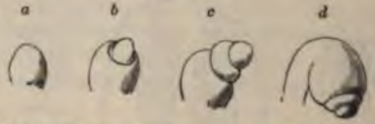
*Pinus sylvestris*. A. Carpel with two naked ovules; *a*, micropyle. B. Carpellary scale of ripe cone, with seeds (*a*). C. A seed separated (*a*), having a wing-like process. D. Vertical section of the seed (C, *a*). E. Young plant from germinated seed.

860. The phenomena presented in other Pinaceæ, in *Taxus*, and in the Cycadaceæ agree in most of the essential particulars. There appear to be some curious peculiarities in the Gnetaceæ, which are not yet completely made out. In *Welwitschia*, whose anomalous structure has been described at p. 407, the embryo-sacs grow out of the primary embryo-sac.

### *Ovules of Angiospermia.*

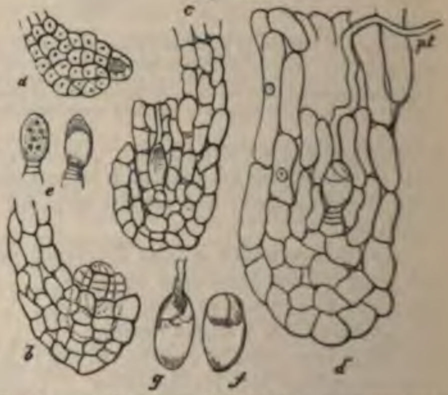
861. The early history of the ovules of this group is analogous to that of the ovules of Gymnosperms, excepting in the particular that they arise from the placentas existing in closed ovaries instead of being developed upon the exposed surfaces of open carpels.

Fig. 552.



Ovules, showing gradual formation of coats over the nucleus and progressive curvature.

Fig. 553.



Development of the ovule of *Orchis Morio*: *a*, a young ovule, with the nucleus projecting from the inner coat; *b*, an older ovule becoming anatropous, with the outer coat growing up over the inner; *c*, section of a more advanced ovule; *d*, section of an ovule with the pollen-tube (*p t*) passing down the micropyle, and in contact with the embryo-sac; *f*, an embryo-sac extracted, with three germinal corpuscles; *g*, another, with the end of a pollen-tube adherent. Magn. about 100 diam.

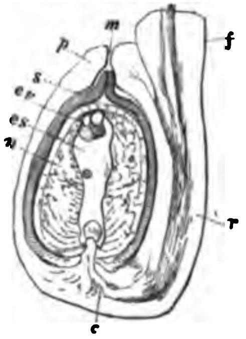
The ovules arise from the placentas as minute cellular papillæ, which gradually take form, and exhibit the regions and the modifications of their arrangement described in an earlier section.

The annexed drawing (fig. 553)—actual views, drawn to a scale, of the development of the minute ovules of *Orchis*—illustrate the gradual formation of the coats &c. Fig. 553, *a*, represents a young ovule projecting out from the placenta, before it has become anatropous; the nucleus here consists merely of the embryo-sac surrounded by a single layer of cells, which layer is absorbed as the ovule grows (*c*, *d*), so that the embryo-sac constitutes the whole nucleus of this ovule. In *a* the inner integument partially encloses the nucleus; in *b* the outer integument has grown up over this to a certain extent; and both are still more developed in *c*, where the inner coat has covered up the nucleus (leaving the *endostome*, § 236), but itself projects from the outer coat. In *d* the outer coat has grown up over the inner, and the *micropyle* or *foramen* (§ 236) consists of a wide exostome and a narrow endostome, into which the pollen-tube (*p t*) has penetrated.

Ovules are seldom so small, or composed of so few cells, as the foregoing; more frequently the nucleus is a cellular mass of some size, and the coats are composed of several strata of cells. The outer coat is the *primine*, the inner the *secundine*, of Mirbel.

862. At the epoch when the pollen is scattered from the anthers, the ovule presents the characters which are illustrated in fig. 554, which represents the anatropous ovule of the garden Hyacinth. The nucleus (fig. 554, *n*) is surrounded (in this case) by two coats (*s* & *p*), which are perforated above by a canal, the micropyle (*m*); at the base of the nucleus is the chalazal region (*c*), whence the integuments (*s* & *p*) arise, and where the *raphe* (*r*), with its spiral vessels, ends. In the centre of the nucleus is a long sac (*e s*), the embryo-sac. It is a large cell, filled with watery fluid and protoplasm, and contains at its summit the *germinal corpuscles* (*e v*), globular or oval masses of protoplasm, one of which becomes the germinal vesicle.

Fig. 554.



Vertical section of the ovule of the garden Hyacinth, just before impregnation; *f*, funiculus; *r*, raphe; *c*, chalaza; *n*, nucleus; *s*, inner integument; *p*, outer integument; *m*, micropyle; *e s*, embryo-sac; *e r*, germinal corpuscles, one of which gives origin to the embryo. Magn. 25 diam.

Some authors assert that these corpuscles are *cells* before impregnation; but we hold that they are merely corpuscles of protoplasm, or rather free primordial utricles (§ 700), like the unfertilized spores of *Fucus* (§ 832). In fig. 556, A, *e r*, is shown the condition before fertilization in *Santalum*. Most observers consider that the germinal vesicles exist before fecundation; but Tulasne inclines to the belief that they are the first results of that process. In some cases, at the bottom of the embryo-sac, small cells (*antipodal cells*) have been seen, which have only a temporary existence, and disappear after fertilization. The purport of these cells is not known.

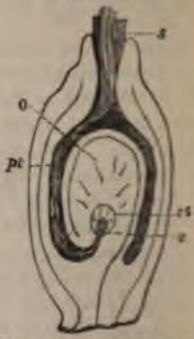
863. The embryo-sac exhibits different modes of development in different Orders of plants. In the Orchidaceæ the cell which constitutes the embryo-sac (fig. 553) very soon obliterates the surrounding cells, here a single layer, and comes to form the entire nucleus (*c*, *d*, *e*, *f*). In the Compositæ an analogous condition is met with. In the Leguminosæ the embryo-sac sometimes expands so as to cause the absorption even of the inner integument.

On the other hand, it often only occupies a moderate part of the nucleus (fig. 554), and may then be a simple cylindrical or oval sac, or run out into pouches or *diverticula*, as occurs especially in Scrophulariaceæ. A remarkable condition occurs in Santalaceæ, where the apex of the embryo-sac grows out from the micropyle to meet the pollen-tubes, much as in *Ephedra* or *Welwitschia*, wherein the coat of the ovule is prolonged into a styliform process; in *Santalum album* and some other plants the embryo is developed entirely outside the nucleus, in the protruded part of the sac.

864. When the pollen-tubes are formed in the stigma (§ 856), they gradually elongate by growth at the apex into tubes which pass down the canal of the style when this exists, the latter being sometimes several inches long. The time occupied in this growth varies from a few hours to a week or two. The pollen-tubes mostly die away above as they grow below; and the stigma withers soon after the pollen-tubes have penetrated.

It is remarkable that the stigma remains fresh for a considerable time in unfertilized ovaries; and in the occasional cases of development of an unfertilized ovule, which has been observed in some diœcious plants, as *Cœlebogyne*, Hemp, *Mercurialis*, &c., the stigma does not wither.

Fig. 555.



Vertical section of the ovary, containing one ovule, of *Carduus*: *s*, base of the canal of the style; *o*, body of the ovule; *p t*, bundle of pollen-tubes, descending from the stigma; *e s*, embryo-sac; *e*, nascent embryo. Magn. 25 diam.

865. The pollen-tubes are exceedingly minute, the diameter averaging from $\frac{1}{4000}$ to $\frac{1}{7000}$ of an inch. But Amici estimated the number of pollen-tubes formed from the pollen-masses of *Orchis Morio* at 120,000. Experiments have shown, however, that, under favourable circumstances, a very few pollen-grains suffice for even a many-ovuled ovary. Kölreuter found that when 25 pollen-grains were placed on the stigma of *Hibiscus Trionum*, 10–16 ovules were developed; with 50 or 60 grains, above 30 ovules; and 1, 2, or 3 at the most sufficed the single ovules of *Mirabilis Jalapa* and *M. longiflora*.

The bundle of pollen-tubes proceeding from the style is distributed in fractions, or partial bundles, to the placentas, when several of these exist. The pollen-tubes make their way to the points of the ovules (figs. 555, *p t*, & 553, *d*, *p t*), and one or two enter the micropyle of each. Generally speaking, the tube ceases to elongate when it reaches the outer surface of the apex of the embryo-sac. Sometimes it runs onwards a little way (fig. 553, *g*), often depressing the membrane of the embryo-sac a little. According to Hofmeister, it actually breaks through into the embryo-sac in *Canna*. In all cases it contracts a firm adherence, and possibly a kind of conjugation takes place (fig. 556, B).

866. The arrival of the pollen tube upon the surface of the em-

bryo-sac is followed by the development of one (rarely of more) of the germinal corpuscles (fig. 556, A, *e v*) into the *germinal cell* (fig. 556, B, *e v*).

In Orchis, two of the corpuscles are sometimes developed into embryos. In *Citrus*, as may be readily observed in Orange-pips, two embryos are very frequently formed in the seed.

Fig. 556.

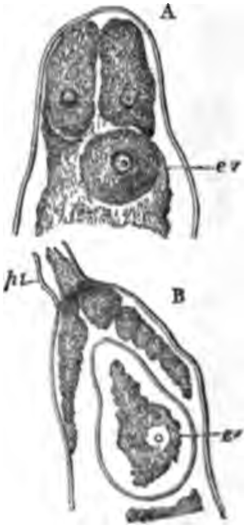


Fig. 557.

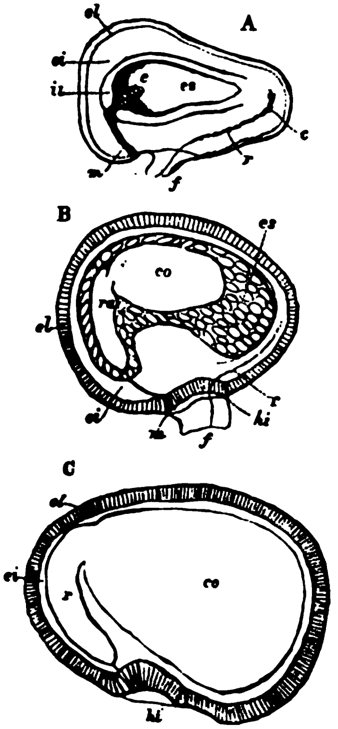


Fig. 556. Apex of the embryo-sac of *Santalum album*: A, just before impregnation; B, with the pollen-tube (*p t*) adherent, and a cellulose membrane upon the germinal cell (*e v*). Magn. 400 diam.

Fig. 557. Development of the embryo and seed of *Tetragonolobus purpureus*. A. Section of a seed soon after fertilization: *e*, embryo, in the upper end of *e s*, the embryo-sac, which in this stage is all that remains of the nucleus; *i i*, internal integument; *e i*, external integument; *e l*, epidermal layer; *m*, micropyle; *c*, chalaza; *r*, raphe; *f*, funiculus. B. Section of half-ripe seed, with internal integument obliterated, and the embryo-sac filled with endosperm-cells: *co*, cotyledon; *ra*, radicle of the embryo; *hi*, hilum; other references as in A. (This section represents a condition which is *permanent* in albuminous seeds.) C. Section of a ripe seed, in which the growth of the embryo has obliterated the endosperm, and the seed consists merely of embryo and testa; the latter is composed of the persistent external integument with its epidermal layer.

867. The development of the germinal cell into the *embryo* exhibits some variations in different cases. Most frequently the cell divides transversely, and the upper cell often elongates (sometimes dividing again by septa) so as to form a tubular confervoid filament, or *suspensor*, hanging from the top of the embryo-sac, and bearing at its lower end the true *embryonal cell*, which soon becomes a mass of cells, which are ultimately shaped into a mono- or dicotyledonous embryo. This suspensor is seen especially in Cruciferæ, Scrophulariaceæ, &c.; it is a single globular cell in *Potamogeton*. In *Zea*, *Fritillaria*, &c. the germinal cell does not elongate at all. In *Orchis* the *suspensor* grows out from the micropyle.

868. Different changes are undergone by the parts of the ovule during the development of the embryo (fig. 557). In exalbuminous seeds (§ 298), the embryo in its growth destroys all trace of the *nucleus*, and in the ripe seed lies immediately within the coats. In seeds with albumen or endosperm (§ 299) the commonest condition is for the embryo-sac to become filled with cells which are moulded over the embryo internally, and to expand externally until the surrounding tissue of the nucleus disappears, or remains only as an element in the coats of the seed. The tissue developed in the embryo-sac forms the albumen. In Piperaceæ, Nymphæaceæ, and a few other cases a double albumen is formed (§ 299), endosperm being formed both inside and outside the embryo-sac, the latter being developed from the tissue of the nucleus.

No rules can be given for the homologies of the "coats" of the seed—the *testa* and *tegmen* or *endopleura*,—which are formed either from the *primine* and *secundine*, or from these and the *nucleus*—and sometimes from one alone of them, its tissues undergoing a different development in different layers.

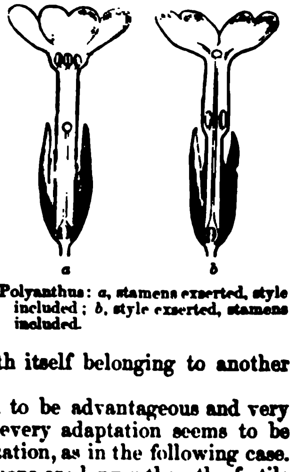
### *Fertilization.*

869. In the preceding paragraphs the structural arrangements of the sexual organs of flowering plants and the manner in which the embryo is formed have been described; it remains now to speak of certain curious phenomena that have been observed relating to the process of fertilization. The existence of distinct sexes in plants was inferred by Linnæus from certain arrangements which he described, and which would favour the process of fertilization, though it was soon seen that in many instances, as in the case of bisexual plants, the agency of the wind or of insects was required to convey the pollen to the stigma. Except in the instances just alluded to, it was the general opinion that self-fertilization was the rule in hermaphrodite flowers, *i. e.* that the stamens of any given flower shed their pollen on the stigma of the same flower. Sprengel, however, and recently Darwin have done much to prove that though

a flower may be structurally hermaphrodite, it is usually functionally bisexual, and that a greater number of healthy seeds are produced when a cross-fertilization between the stamens of one flower and the pistil of another flower of the same species is effected. Darwin even states that in those cases where self-fertilization is the rule, a cross occasionally occurs.

The facts just mentioned may be illustrated by the case of the common Primrose, the flowers of which are dimorphic: in some the stamens are long and protrude beyond the corolla; in others the style is long and projecting, while the stamens are concealed within the corolla. Now the greatest number of fertile seeds are formed when pollen from the long stamens is made (by insect agency or otherwise) to pass, not on to the short style of the same flower, but on to the long style of another flower. Other plants, such as *Lythrum Salicaria*, are trimorphic, having styles and stamens of three different lengths. Reciprocal fertilization is possible between any two of these; but the most perfect fertilization occurs when the style of one flower is impregnated with pollen from a stamen of equal length with itself belonging to another flower.

Fig. 558.



Polyanthus: *a*, stamens exserted, style included; *b*, style exserted, stamens included.

Though cross-fertilization is thus shown to be advantageous and very general, yet there are some cases where every adaptation seems to be made with the view of securing self-fertilization, as in the following case. In *Dombeya* the staminodes or sterile stamens are longer than the fertile ones, and are endowed with a power of movement in virtue of which they curve downwards and outwards, so as to come into contact with the fertile stamens, whose anthers open outwardly. In this manner the staminodes become dusted with pollen, and then become uncoiled, assume an erect position, so as to come into contact with the stigma, whose curling lobes twist round them and receive the pollen from them.

Hildebrand gives the following arrangement of the distribution of sexual relations in flowering plants:—

A. Male and female organs in different flowers (diclinous), self-fertilization consequently impossible, and foreign impregnation, accomplished by insect agency or wind, indispensable. Under this head are included the flowers of diœcious and monœcious plants.

B. Male and female organs in the same flower (monoclinous).

1. One sex developed before the other (dichogamous). Those flowers in which the male organs reach maturity before the female ones are called protandrous, and those in which the female reach maturity before the male protogynous; self-impregnation is thus naturally prevented, and fertilization is accomplished by insect agency.

2. Both sexes developed at the same time.
   - *a.* Flowers opening.
     - i. Anthers remote from the stigma.
       - A. Length of style on different individuals of the same species diverse (*Heterostylia*). Self-impregnation is not prevented; but, in comparison with impregnation through insect agency, it is either entirely useless for fruit-formation, as in *Pulmonaria officinalis*, or effected only with unimportant results, as in *Primula sinensis*.
       - B. Length of style on different individuals of the same species equal.
         - o. Sexual organs changing their reciprocal position during the development of the flower. Self-impregnation avoided; impregnation by means of insects facilitated.
         - oo. Sexual organs remaining unaltered in position during the development of the flower.
           - † Insect agency necessary to fertilization; self-impregnation in fact impossible, foreign aid indispensable: Orchideæ. Or self-impregnation possible, but not indispensable, foreign impregnation more frequent: Asclepiadeæ.
           - †† Insect agency not necessary to fertilization. Self-impregnation possible, but impregnation also performed by insects.

The possibility of self-fertilization is evident—1, where the flowers are erect and the filaments are longer than the styles, as in *Vitis*, *Chenopodium*, &c.; 2, where the flowers are pendent and the filaments are shorter than the styles, as in *Fritillaria imperialis*, *Convallaria majalis*, &c.; but as all these flowers are visited by insects, cross-impregnation probably often takes place.

- ii. Anthers near the stigma.
  - * No fruit formed without impregnation by insects: *Corydalis cava*.

It would scarcely have been deemed credible that self-fertilization was impossible in such an instance as *Corydalis cava*, where the anthers are closely appressed to the stigma, and in which self-impregnation appears inevitable. In his experiments, however, Hildebrand discovered that when this plant was secured from the visits of insects, and also when the pollen was artificially applied to the stigma of the same flower, no fruit was set. To obtain perfect fruit he found it necessary to impregnate the stigmas of one plant with pollen from another.

- ** Fruit formed as a result of self-impregnation, but impregnation by insects not excluded.

Instances of undoubted self-fertilization of individual flowers are known in the genus *Fumaria*, *Salvia hirsuta*, *Linum usitatissimum*, *Cephalanthera grandiflora*, *Ophrys apifera*, &c.; but the number and quality of seeds borne is less than where cross-impregnation is effected.

β. Flowers not opening.

Self-impregnation alone results, every foreign impregnation being excluded; but these plants all have other flowers which open and are thus exposed to the possibility of extraneous impregnation.

The general conclusions that may be drawn from the above facts are thus given by the author already cited:—

1. The arrangements in the majority of flowers are such that no self-impregnation can take place, but a transport of the pollen from flower to flower is accomplished instead.
2. Insects are necessary in most cases for the conveyance of the pollen.
3. When the access of a flower's own pollen is prevented, it necessarily follows that self-impregnation is impossible.
4. In those cases where self-impregnation is possible, or even unavoidable, the possibility of foreign impregnation is for the most part not excluded.
5. And in these cases insects are active, and accomplish the impregnation of the flowers.
6. There is probably no flowering plant to which access of foreign pollen, at least to a portion of its flowers, is impossible, and continued self-impregnation alone possible—therefore no flowering plant which furnishes a proof against the general law which negatives self-fertilization.
7. By experiments it has been found that where, by accident or design, the pollen of a flower falls on the stigma of the same flower, fertilization either does not follow, or when it does occur the quantity of seed is less than where foreign pollen is employed.
8. A gradual transition may be traced, starting from those cases where self-impregnation is utterly impossible, to those where it is possible and evident, but not to the exclusion of the possibility of a foreign impregnation of the flowers.
9. The sexual relations and mode of fructification do not invariably tend towards the morphological affinities of the flowers. In some isolated families the sexual conditions of all members are alike; in other families, again, and even genera, they are essentially different. The sexual relations, therefore, have not developed with equal pace and in the same way as the morphological relations in the transformation and perfection of flowering plants.

## *Hybridization.*

870. The treatment of the subject of the sexual reproduction of Plants would be incomplete without some notice of the phenomenon of *hybridization*, or cross-breeding between distinct species of plants.

From the difficulties, arising partly from the minute size of the structures, partly from the comparatively recent date of any accurate knowledge of the sexual organs of the Cryptogamia, we are at present only acquainted with a few certain facts in reference to the cross-breeding of species in that Subkingdom. It has long been known, however, that in collections of cultivated Ferns forms spring up from time to time presenting new characters, more or less intermediate between well-known natural species; and these have been commonly accounted hybrids. The discovery of the phenomenon of fertilization on the prothallia (§ 845) of Ferns gives a new support to the supposition that such plants are hybrids, although the question is still insufficiently supported by evidence.

871. We possess, however, some facts of importance on this subject relating to the Fucaceous Algæ. Thuret took advantage of the extrusion of the germ-cells and spermatozoids (§ 832) in Fucaceæ before impregnation to collect these separately and experiment on the degree to which hybridization was possible. He found that spermatozoids of *Fucus serratus* and *F. vesiculosus* would not fertilize the spores of *Ozothallia vulgaris*, and *vice versâ*. Neither could the spores of *Himanthalia lorea* be fertilized by *Ozothallia vulgaris* or *Fucus serratus*, nor the spores of *Fucus serratus* by the spermatozoids of *F. vesiculosus*. But the spores of *F. vesiculosus* impregnated by the spermatozoids of *F. serratus* became fertile and germinated; which fact is the more interesting since *F. vesiculosus* is a variable plant in its natural state, while the others named exhibit comparative fixity.

872. The existence of hybrids in Phanerogamia, produced by impregnating the ovule of one plant with the pollen of another, is a well-ascertained fact; and indeed hybrids are produced at will, within certain limits, by gardeners.

It is necessary to distinguish here between *true hybrids*, or *mules*, resulting from the crossing of distinct species, and simple *cross-breeds* (or *metis*) commonly included under the name of hybrids by gardeners, and resulting from the crossing of varieties (§ 311) of the same species. It is from the last operation that the great majority of the "hybrids" produced in favourite florists' flowers, such as *Pelargonium*, *Fuchsia*, &c., are derived—this cross-fertilization presenting little difficulty, and commonly occurring naturally where large quantities of varieties are grown together.

The ready cross-fertilization of varieties spontaneously, places great difficulty in the way of growing the varieties of cultivated vegetables for seed. The different varieties of the Cabbage, Turnip, Pea, &c. are difficult to preserve pure as seeding-plants in large gardens or seed-growing establishments, from the fact of insects and the wind carrying the pollen from plant to plant.

873. True hybrids can, as a rule, only be produced between plants belonging to the same genus. When they are more diverse than this, they will usually not cross; and even within the limits of genera, species will not always breed together.

Generic difference in Flowering plants usually involves difference in the structure of the reproductive organs, we are therefore not surprised at the above statement; numerous instances, however, occur of the refusal of nearly allied species to cross, where we cannot detect any structural differences between them.

874. The tendency to cross-breeding is less common than is frequently supposed. Gærtner, the greatest experimental authority on this point, states that in 10,000 sets of experiments, carried on during many years, he only obtained 259 true hybrids. It is found impossible, for example, to cross the Gooseberry and the Currant (two species of *Ribes*), the Apple and Pear (two species of *Pyrus*), the Blackberry and Raspberry (allied species of *Rubus*), &c.

Besides this peculiar indisposition to hybridize, there exists an obstacle in nature, in the greater facility with which an ovule receives the influence of its own pollen; Gærtner describes this phenomenon under the name of *elective affinity*, stating that when the natural pollen and that of another species are placed upon a stigma, the foreign pollen remains inert; and even when the natural pollen is applied a little time subsequently to the foreign pollen, it acquires the supremacy, and the embryos prove true, and never hybrids.

875. When species are crossed, the result from the hybrid seed is a plant differing from both parents, bearing more or less relation to one or the other, as regards form and habit, in different cases. Gardeners do not appear agreed as to the kind of influence exerted by the male and female parents respectively, in determining the character of the mule. Gærtner states that in hybrids of *Digitalis* the mules most resembled the female parent, while in *Nicotiana* the reverse appeared; and he believes no law can be laid down in regard to this point.

876. The seeds ripened after hybridizing generally form but a fraction of those matured under natural circumstances. Thus, according to Gærtner, hybrids of *Verbascum Lychnitis* with *V. nigrum* gave but 63 per cent. of the normal number, with *V. Thapsus* 21 per cent., with *V. pyramidatum* 3 per cent.; hybrids of *Dianthus barbatus* with *D. Armeria* 53 per cent., with *D. deltoides* 22 per cent., with *D. virgineus* 1 per cent., &c. Moreover diœcious plants appear less prone to hybridize than those with hermaphrodite flowers.

877. The seeds originating from a process of hybridization produce plants varying very much in their degrees of fertility. It appears that the majority are barren; in many cases only a portion of the seeds formed produce fertile plants; while in a few cases the hybrid plants are nearly as fertile as those of their parent species when unmixed. It is observed also that in fertile hybrid plants the flowers earliest opened are the most fertile, or sometimes are the only ones that ripen seed, subsequent flowers often developing fruits the seeds of which are destitute of an embryo.

This barrenness of the later flowers, from deficient vital force, is in some degree analogous to what we sometimes observe in cut flowering stems of succulent plants. We have seen the ovary swell, and one or more seeds become extensively developed on a cut spike of *Aloe* and on an umbel of *Crinum*, thrown aside to wither. The seeds, however, were quite "blind," the expansion consisting of an abnormal development of the integuments of the ovule, the nucleus and embryo-sac remaining unchanged.

878. In some fertile hybrids it is observed that their progeny forming the second and third generations become more fertile than the original hybrid; it is noticed, however, that their descendants usually exhibit a great tendency to vary in external character, and often return more or less to the type of one of the parents.

Hybrid characters seem, from the researches of Naudin, not to be permanent. The plants revert, as above said, to the type of one or the other of the parents. What are termed "*sports*" by gardeners, *i. e.* shoots differing in character from those on the other portions of the plant, are frequently, but not always, due to a dissociation of hybrid or metis characters.

879. The impregnation of the ovules of hybrids by the pollen of plants of either parent species produces more fertile seeds than are formed after self-fertilization of hybrids. The progeny in such cases return more or less to the parent type, on the side from which the pure pollen comes, and by a repetition of such fertilization the hybrid characters are lost in a few generations.

It is an interesting fact that the ovules of hybrids are sometimes more freely fertilized by pollen of a strange but pure species, than by their own: thus the hybrid *Nicotiana paniculato-rustica*, which usually did not ripen more than 13 good seeds in a capsule, produced with the pollen of *N. paniculata* 36, with *N. rustica* 20, and with the pollen of *N. Langsdorfii* (a totally new element in the crossing) 16. In another experiment, when this hybrid produced no seeds by self-fertilization, 10 good seeds resulted from crossing with *N. Langsdorfii.*

880. A curious phenomenon has been observed in the garden plant called *Cytisus Adami*, obtained either by grafting or true hybridation of the two kinds of Laburnum, *Cytisus Laburnum* and *C. purpureus.* The plants have in many instances exhibited a partial separation or dissolution of the hybrid characters in the products of different leaf-buds: on the same tree in which part of the branches bore blossom of the hybrid character, other shoots occurred, some of which had reverted to the character of *Cytisus Laburnum*, others to that of *C. purpureus*, the other parent. In some of the shoots, moreover, unequally combined characters of the parents were observed in different flowers of the same raceme.

In some cases it has been found that the reverted or pure shoots bore perfect seeds, while the hybrid blossoms were barren.

*Cytisus Adami* has generally been supposed to be an ordinary hybrid; but it has recently been stated that it originates when *C. purpureus* is grafted on *Cytisus Laburnum*, offering thus an instance of affection of the stock by the scion analogous to that of the variegated Jasmine and Abutilon referred to above (§ 813). If this prove true, it will be a most important physiological fact, opening a very interesting field for experiment, likely to lead to practical results of high value in the cultivation of fruit-trees. Certain *sports* of Roses have also been explained by graft-hybridization; but these cases require strict scrutiny before they can be absolutely stated to result from grafting.

### *Germination.*

881. Seeds placed under favourable circumstances germinate. They are capable of doing so even before they are fully ripe.

The conditions favouring germination are the presence of moderate heat, moisture, and oxygen gas. Water is absorbed; and substances contained in the seed are oxidized, with the evolution of carbonic acid, and sometimes of carbonic oxide and ammonia; and the starchy substances laid up in the cells become converted into soluble sugar and ready to supply the material for development. During this process much heat is evolved (see § 885).

Many seeds germinate very quickly when placed in favourable conditions, especially those of Cruciferæ, Grasses, many Leguminosæ, Cucurbitaceæ, &c.; but the period varies, and is greatly affected by the degree of heat to which they are subjected, the depth of sowing, which, on the one hand, provides against desiccation, and, on the other, removes the seed further from the influence of the oxygen of the atmosphere.

Seeds with a hard pericarp or endocarp (§§ 243, 244) enclosing the seed, such as those of *Rosa*, *Cratægus*, Almond, or with a hard testa (§ 296), *Pæonia* &c., often remain in the ground a year before they sprout, unless previously soaked in warm water. Every kind of seed germinates more freely at one temperature than at another. Seeds are very variable in this respect.

Chemical changes are observed in the germination of the *spores* of Cryptogamia: in the resting condition they contain oil and albuminous matters, which are decomposed before germination and resolved into chlorophyll, dextrine, &c.

882. The result of germination is the appearance of the organs of vegetation and first of all of the root or radicle, which is to serve as the organ of absorption for the new plant. This almost universally turns downward, in whatever position the seed may lie, and penetrates the soil (see § 706).

# CHAPTER VI.

## MISCELLANEOUS PHENOMENA.

### **Sect. 1.** Evolution of Heat by Plants.

883. In examining the cases falling into this section, it is important to separate them into two classes:—(1) those relating to the proper or specific heat of plants generally; and (2) those more remarkable instances of elevation of temperature occurring at certain periods of development in particular plants.

884. It being a well-ascertained fact that the chemical combination or separation of various elements found in plants is accompanied by increase or diminution of sensible heat, and that the process of evaporation, constantly going on in dry weather in healthy plants, is a cause of depression of temperature as the substance from the liquid passes off in the form of vapour, it is evident that the proper temperature of plants, and their organs and tissues, must vary greatly according to the circumstances in which they are placed. Yet, as the evaporation, and the fixation of carbon in a solid form from gaseous material—both "cooling processes"—are such preponderating operations in the nutritive and assimilative processes of vegetation, it seems scarcely possible, under ordinary circumstances, that plants should have a specific heat rising above that of the surrounding atmosphere.

885. The germination of seeds, in which carbonic acid is abun-

The different power of conducting heat possessed by the several tissues, and, in the case of the woody tissues, the difference in the conducting-power according to the varying directions of the fibres, together with the disturbances arising from the unlike conductivity of the fluids and solid matters constituting in the cell-contents, render it very difficult to arrive at any general conclusions as to the specific heat of plants.

From Dutrochet's experiments, made with a thermo-electric apparatus, it would appear that the specific heat of all parts of plants in their ordinary condition is rather lower than the temperature of the surrounding atmosphere. In cases, however, where evaporation was prevented by placing plants in an atmosphere saturated with moisture, the temperature sometimes rose from $\frac{1}{12}$ to $\frac{1}{3}$ per cent. above that of the atmosphere. Moreover a rise and a fall took place in the course of twenty-four hours, the maximum occurring between ten and two in the day, the minimum at midnight. It was further observed that the specific heat was only discoverable in the soft or green parts, not in the woody structures.

The experiments, however, which have been made to determine these points are by no means conclusive. It seems probable that the increased heat observed in the structures of plants when evaporation is restrained depends upon the slow combustion of carbon, which is enabled to manifest itself when the cooling influence of evaporation is removed.

dantly evolved, is constantly accompanied by a rise of temperature, which is satisfactorily accounted for on chemical principles; and the "heating" of heaps of germinating seeds is the more marked in consequence of the "fermentation" (or decomposition through contact-action, § 741) by which it is always accompanied.

886. The most remarkable instances of evolution of heat are those which occur during the flowering of plants. This rise of temperature appears to take place in all cases; but it is most strikingly displayed, of course, in plants which have a crowded inflorescence, and above all when this is surrounded by a structure confining the liberated heat, as in the spathes of the Araceæ, on which many observations have been made.

*Arum maculatum*, *A. italicum*, *A. Dracunculus*, *Richardia æthiopica*, *Colocasia odora*, &c., the male inflorescence of *Cycas circinalis*, the large solitary flowers of *Cactus grandiflorus*, *Bignonia radicans*, *Victoria regia*, &c. are among the recorded plants in which the rise of temperature has been observed.

The greatest evolution of heat, after the opening of the spathe of Araceæ, is at the part where the male flowers are situated: after the pollen has been discharged, the upper parts of the spadix grow warmer, and the lower parts cool gradually upwards.

Experiments made to ascertain the cause of this heat lead to the conclusion that it is attributable to a process of combustion. Saussure found that the flowering spadix of *Arum maculatum* abundantly absorbed oxygen; and Vrolik and De Vriese, comparing the temperatures attained by a spadix placed in oxygen gas and by one placed in common air, found that the former always exceeded the latter, while a spadix kept for a longer time in nitrogen gas did not manifest any increased temperature.

887. Connected with the subject of the temperature of plants are the interesting observations of Alph. De Candolle on the different external temperatures required by different plants to stimulate them into either vegetative or reproductive activity. It is well known that any given plant will require a certain sum of heat during a season to enable it to go through its whole course of development, and that under certain limits the course of development will be passed through proportionately more quickly in warmer climates. Further, it is known that most plants of warm climates are killed by certain degrees of cold. But it is further observed that certain temperatures, insufficient to injure plants, are at the same time insufficient to "start" them into growth, and that different species of plants have different constitutions in this respect; while, on the other hand, excessive temperatures may render plants barren by over-stimulating vegetative action, as is observed in the Vine in the tropics, and commonly also in badly managed exotics in our hothouses.

## Sect. 2. LUMINOSITY.

888. In most botanical works we find noticed the observation of the daughter of Linnæus, that she perceived a peculiar flashing luminosity of the flowers of *Tropæolum majus* on a hot summer's night—together with a statement that the same appearance has been observed in the orange Lilies, Sunflower, Marigolds, &c. The fact that all physiologists, from Saussure downward, who have sought to repeat these observations, have failed, and that the appearance is always assigned to orange or red flowers, leads to the belief that the statements are founded on error, arising from the peculiar effect of these tints upon the eye. The influence upon the eye of the brilliant orange and crimson flowers of some of the Rhododendrons and Azaleas now grown in our gardens is very similar to that of looking upon a luminous body. The asserted luminosity of flowers is certainly at present a very questionable matter.

889. On better authority, namely of Humboldt, Nees von Esenbeck, Unger, and others, rests the fact that the thallus of some Fungi is luminous in the dark. The imperfect thalloid structure described as *Rhizomorpha subterranea*, occasionally met with in mines, exhibits upon its ramified structure points which possess an irregular phosphorescence, sometimes rising to such a degree of luminosity as to enable surrounding objects to be distinguished. According to Unger's observations, the light is not emitted from decaying matter, but from a peculiar superficial layer of cellular tissue.

Phosphorescence has been observed in other mycelia, and it is also exhibited in the perfect Fungus of *Agaricus olearius* and other species.

Rotting wood is well known to be often phosphorescent; and some authors state that this does not depend upon the presence of Fungi; but, seeing the proved occurrence of phosphorescence in the mycelium of Fungi, it is most probable that the luminosity is attributable to them, especially as it is removed irrecoverably by drying up the damp rotten wood.

890. The statement that the Moss *Schistostega osmundacea*, which grows on the roofs of caves, is phosphorescent, has been declared by Milde to be erroneous. We could detect no trace of it in observations made some years ago, and we agree with Milde in attributing the appearance to the glistening caused by the reflections and refractions of light on the wet surface of the cellular leaves.

According to Martius, the milky juice of *Euphorbia phosphorea* becomes luminous when removed from the plants and heated gently.

## Sect. 3. MOVEMENTS OF PLANTS.

891. The absence of the phenomena of motion was formerly imagined to constitute one of the distinguishing characters of plants

as contrasted with animals; but, in fact, members of the Vegetable Kingdom not only exhibit partial movements of their internal or external structures, but in some cases the entire organism has the power of locomotion.

The movements, however, of different plants are dependent upon very diverse causes, some of them being entirely mechanical, and due to physical affections of the tissues by the conditions of the surrounding atmosphere, and to alternate conditions of turgescence and exhaustion; others are mechanical in appearance, but excited by causes which simple physical laws will not explain; while a third kind depend upon the contractile quality of the protoplasmic substances, which gives rise to automatic movements comparable to those of the lower animals and to the ciliary motion found in particular tissues of the highest animals.

892. To the first of these classes belong such phenomena as the bursting of seed-vessels, anthers, &c., attributable to the hygroscopic conditions of the tissues, which, possessing unequal power of imbibition and unequal elasticity, are torn apart or curved in various ways by unequal contractions and expansions, caused by access or abstraction of moisture. These are cases of what is called in common language "warping," and can scarcely be regarded as vital phenomena, being definite modes of destruction of dead structures, resulting from special structural conditions.

893. The second class of movements are those exhibited periodically, or under special stimulus, by the external organs of plants, such as the "sleeping" and "waking" of leaves and flowers, and the movements of the Sensitive Plants, &c. To these may perhaps be added the less striking, but not less enigmatical, movements which cause the twining condition of stems &c.

894. The movements of the third class are those already adverted to in former sections, where the protoplasmic matter of cell-contents, or free bodies, such as zoospores, spermatozoids (§ 737), or even perfect individuals, such as *Desmidieæ*, Oscillatoriaceæ (p. 439), exhibit temporary or permanent power of locomotion.

The *rotation* of the protoplasmic cell-contents (§ 736) doubtless depends upon (imperfectly understood) causes similar to those which render many of the simpler plants locomotive; and the movements exhibit the closest resemblance to those of some of the Protozoa in the Animal Kingdom—in particular, of *Amœba* and its allies. The locomotion of free products of the cell-contents, such as zoospores and spermatozoids, is generally immediately resultant from the movement of *cilia* existing upon their surface; and the same statement applies to the locomotion of the "cell-families," which form the representatives of species in the Volvocineæ (p. 440). The locomotion of the Oscillatoriaceæ and Diatomaceæ (p. 439), however, does not appear to be effected through the agency of cilia; at all events no such structure can be detected with our present means of observation.

The ciliary motion of the unicellular plants and reproductive bodies is, although inexplicable, a more general phenomenon of life than the movement of the Diatomaceæ &c., where these organs are not detected. Some authors incline to regard the motion of Diatomaceæ as dependent upon osmotic currents, resulting from the interchange of matter between the cell-contents and the surrounding water.

895. Movements of various kinds, more or less mechanical in appearance, take place in the higher plants through the *power of imbibition* and the *elasticity* of their tissues; these movements are generally immediately produced by stimuli of various kinds disturbing the equilibrium in the tissues.

Great difference in the power of imbibition exists in different kinds of cellular tissue—collenchymatous tissue (§ 619), for example, swelling out when wetted, and contracting when dried, far more than woody structures. Experiments have shown that the degrees of expansion and contraction vary in different plants and tissues of plants in a range from $\frac{1}{1077}$ to $\frac{1}{4}$ the diameter of the cells. In cases of great contraction a wrinkling of the cell-membrane is generally involved.

All living cell-membranes possess a certain degree of elasticity; and consequently a certain amount of difference of dimensions is dependent upon the degree of tension or turgescence of the cell from the presence of fluid contents. Cells in which osmotic processes are going on are constantly in a state of greater or less tension.

The expansion of cellular tissue through turgescence, permitted by the elasticity of the membranes, appears to have a much smaller range than the expansion by simple imbibition. The experiments of Unger and of Brucke give a range of $\frac{1}{80}$ to $\frac{1}{5}$.

896. It is evident that the elasticity of parenchymatous tissues must be capable of exerting influence on the position, form, and direction of the organs of which they form part. Supposing a tissue to be uniformly developed, its expansion through turgescence need not alter the general form, nor the relative position of the parts; but if unequal endosmose take place in different parts, causing disturbance of the equilibrium of turgescence, curvature and distortion must ensue. Again, if an organ is composed of regions in which the tissues differ in degree of elasticity, it may suffer a disturbance of the equilibrium of turgescence still more readily; and this is probably the cause of most of the automatic movements of organs of plants.

897. The equilibrium may be disturbed by various stimuli, mechanical and chemical. When an organ is strikingly affected by mechanical influences, we have the phenomenon of "irritability," such as we see in the Sensitive Plants, *Dionæa*, &c. The "sleep" of plants

is doubtless a phenomenon differing only in degree; and this slower movement is probably attributable to the chemical action of light.

898. The movements of plants consist for the most part of the curvature or the folding-up of organs; and in such cases the organs are always found to possess certain peculiarities of structure and mode of union to other organs.

The movements take place periodically (in consequence of the regular alternations of external influences), or irregularly (from the accidental influence of special stimuli).

899. Periodical movements are more particularly connected with the influence of heat and light; and their degree is generally more or less proportionate to the intensity of these influences.

The most common kind of movement is that in which expanded leaves or floral envelopes return to the position which they originally occupied, or close up into the same folds which they exhibited in the buds.

Compound leaves, like those of Leguminosæ for instance, display a simple or compound movement; in the Bean (*Faba vulgaris*) the leaves fold upwards, in *Lupinus* downwards, in *Tamarindus* to the side. In *Amorpha fruticosa* and *Gleditschia triacanthos* the rachis or common petiole of the compound leaves rises or sinks, while the leaflets turn downwards or to the side. In *Mimosa pudica* the leaflets fold together, the partial petioles approach each other, and the rachis or main petiole sinks down.

900. When such movements of leaves or foliaceous organs occur at particular hours, and the structures remain in the new position until the recurrence of a particular period, the closing up is called the *sleep of plants*, which is observed both in green leaves and in the petals of flowers.

The epoch at which the movements take place is very varied. Ordinarily, *leaves* expand in the daylight and close towards evening, while flowers exhibit a great diversity of habit in this respect—so much so, indeed, that Linnæus was enabled to draw up a list of flowers, fancifully termed a "floral clock" (*horologium Floræ*), in which a periodical movement (opening or closing) marked each succeeding hour.

*Ipomœa Nil* and *Calystegia sepium* open their flowers at 3–4 A.M.; *Tragopogon* at 3–4 A.M., closing again before noon; the *Nymphæa*, *Nuphar*, *Lactuca*, &c., about 6 A.M.; *Anagallis arvensis*, 8 A.M. (closing again when the sky is overcast); *Ornithogalum umbellatum*, 11 A.M.; Mesembryanthaceæ generally about 12; *Silene noctiflora*, *Œnothera biennis*, *Mirabilis Jalapa*, &c., 5–7 P.M.; *Cereus grandiflorus* &c., *Datura*, *Mesembryanthemum noctiflorum*, &c., 7–8 P.M.; *Victoria regia* opens for the first time about 6 P.M., and closes in a few hours, then opens again at 6 A.M. the next day, remaining open until the afternoon, when it closes and sinks below the water.

Some closing flowers may be caused to open by exposure to strong artificial light (*Crocus*, *Gentiana verna*); on others (*Convolvulus*) this has no effect.

901. In most of the periodical movements the motion is very slow; but certain exceptions to this exist. Thus in the leaves of *Desmodium gyrans* and other species, the *labellum* of *Megaclinium falcatum*, the styles of *Stylidium adnatum*, and others, the movement is quick enough to be directly perceptible.

In *Desmodium gyrans* (the Telegraph-plant) the trifoliolate compound leaf has a large terminal leaflet, and a smaller one on each side. When this plant is exposed to bright sunlight, in a hothouse, the end leaflet stands horizontally, and it falls downward in the evening; but the lateral leaflets move constantly during the heat of the day, advancing edge first towards the end leaflet, and then retreating and moving towards the base of the common petiole, alternately on each side, in a manner very well compared to the movements of the arms of the old semaphore telegraphs. In *Megaclinium falcatum* (Orchidaceæ), when exposed to sufficient heat, the labellum rises and falls slowly in periods of several minutes; this structure is also *irritable*, and moves more quickly, with an oscillatory motion, when touched.

902. Irregular or irritable movements take place in a great variety of plants, of which the following paragraph contains the most striking examples:—

*Leaves*: The "Sensitive Plants" (*Mimosa pudica*, *sensitiva*, *casta*, and many other species); *Æschynomene sensitiva*, *indica*, *pumila*; *Smithia sensitiva*; *Desmanthus stolonifer*, *triquetris*, *lacustris*; *Oxalis sensitiva*, and, in less degree, *Oxalis stricta*, *Acetosella*, *corniculata*, *Deppei*, &c.; *Robinia Pseudo-acacia* folds its leaves when violently shaken in the morning; lastly, *Dionæa muscipula*, the Venus's Fly-trap.

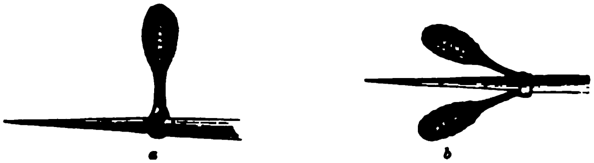
In the case of the sensitive plant (*Mimosa pudica*) there is a swelling at the base of the petiole, the cells of which constitute, as it were, two springs acting in contrary directions, so that, if the one from any cause be paralyzed, the other pushes the leaf in the direction of least resistance. These springs, if they may be so called, are set in action by the rush of fluid creating a turgid state of the one set of cells and an empty state of the other. What circumstances regulate the turgescence are only imperfectly known. The spontaneous slow movement which occurs at stated periods (movements of sleeping and waking) is different from the sudden motion caused by external stimuli. Ether paralyzes the latter, but has no effect on the spontaneous movements. There is no special contractile tissue in these plants.

*Stamens*—curving towards or away from the stigma and dehiscing when touched: *Berberis vulgaris* and other species, *Parietaria judaica*, *Sparmannia africana*, *Cereus grandiflorus*, *Helianthemum vulgare* and other species, and various plants of the tribe *Cynareæ* (§ 443). Other curious movements of the stamens and pistils, and also of the staminodes, are alluded to under the head of Fertilization (§ 869).

*Style*: *Goldfussia anisophylla*, *Martynia*, *Mimulus Lewisii*, &c.

903. The peculiar movements of the pollen-masses of Orchids have already been alluded to (p. 383). Another illustration from *Orchis pyramidalis* may here be given. In this plant the two caudicles of the pollen-masses are connected together by a saddle-shaped disk, the pollen-masses when in the anther being nearly vertical in direction and parallel one to the other. When removed from the anther by the proboscis of an insect or the point of a needle (fig. 559, *a*) the saddle-like disk contracts so as to attach the pollen-mass to the needle &c. Then occurs, first a divergence of the two pollen-masses one from the other, and subsequently a depression, so that they assume a nearly horizontal direction (fig. 559, *b*). In this position they are so placed as to come into contact with the V-like stigma of another flower and thus effect cross-fertilization.

Fig. 559.



*Orchis pyramidalis*: *a*, pollen-masses just removed from the anther, vertical; *b*, pollen-masses divergent and horizontal.

904. Those movements of young stems and appendicular organs by which they coil spirally round bodies supporting them are attributed by some authors to a kind of irritability, the stimulus of the contact with the supporting body causing the growing stem to curve itself over continually, producing ultimately a coiled condition. The direction of the turns of the coil, right or left, depends upon special tendencies of the particular plants, some (Hop) turning to the right hand, others (*Convolvulus*) to the left (the observer supposing himself to stand in the axis of the spiral).

905. This explanation of the coiling of stems is not very satisfactory, nor are those which are offered of the curvature of the growing-points of plants and the upper faces of leaves towards the light. If a leafy shoot of any plant is bent down, without injury, so as to reverse the usual position of the faces of the leaves, the latter will twist upon their petioles and turn their upper faces to the light. Shoots of slender-stemmed, quick-growing plants, such as the Jasmine, *Ampelopsis*, &c., when trained into a dark recess, turn their growing-point backwards in a sharp curve, and grow towards the light, the leaves on the older part of the stem also twisting round to face the light. The influence of lateral light is distinctly seen in plants grown in rooms, in front of windows; while

the "drawn-up" condition of closely planted trees is an equally evident result of preponderating top-light.

The phenomena of the movements of climbing plants, including the spontaneous revolving movement of tendrils &c., and that dependent on contact, have been studied in detail by Mr. Darwin, who has shown that organs of the most diverse morphological character may nevertheless exhibit the same phenomena. The movement of depression in the branches of trees in frosty weather has been investigated with great minuteness by Professor Caspary; but the inducing causes of the movements are at present imperfectly known.

It appears, from the evidence at present existing, that the blue and violet rays are the most efficient in causing the growth of stems &c. towards the light. It is certain that the result is not produced by any attraction comparable to magnetic action, but by influence on the development or turgescence of the tissues, since experiment has shown that seedling plants freely suspended or floating in water are not mechanically moved towards light admitted to them from a particular point in a dark chamber.

# PART IV.

# GEOGRAPHICAL AND GEOLOGICAL BOTANY.

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## CHAPTER I.

## GENERAL CONSIDERATIONS.

906. The object of this department of Botany is to determine the laws which rule over the Distribution of Plants in Time and Space. This abstract study is founded upon the facts furnished by Botanical Geography and Geology, or the description of the present and past conditions of the Vegetable inhabitants of the globe, and, in return, supplies those branches of practical inquiry with principles by means of which they may be systematized.

*Botanical Geography*, which undertakes the description of the peculiarities of the vegetation occurring at present upon the earth's surface, and *Botanical Geology*, which pursues the investigation of the conditions of vegetation which have successively existed in different Geological epochs, deal with facts so far distinct in their character that it is most convenient to treat of them separately; but the *principles* are common to both, and may be taken as one subject.

Explanations of the facts which are obtained by geological inquiries can only be securely founded, either directly or indirectly, upon laws derived from facts furnished by experience of existing phenomena; hence the principles laid down in the present chapter are for the most part only actually valid in relation to existing conditions, and, the subject yet being in its infancy, are mostly only speculatively applied to the elucidation of geological phenomena.

### Sect. 1. Influence of External Agents upon Vegetation.

### *Climate.*

907. Plants are endowed with means of diffusing themselves, more or less efficiently in different cases, over the surface of the globe; but in most cases their existence is limited to certain regions or countries. Geographical obstacles prevent their spreading indefinitely:—some

subject to be overcome by accidental influences, such as seas intervening between countries, and the like; others which can neither be conquered nor evaded, such as *climate*, which fixes unalterable limits to the stations which can be permanently occupied by species.

908. That Cold and Heat, Damp and Drought, intensity and duration of Light, the chief constituents of what we call Climate, are the most important of the external influences acting upon plants, is a fact manifest not merely from the conclusions at which we have arrived in the study of Vegetable Physiology, but one which is revealed by the most slender experience of horticulture and the most superficial acquaintance with physical geography.

The nature of the soil doubtless has also much influence on the distribution of plants, dependent less, probably, on its chemical composition than on its mechanical constitution and hygrometric state.

909. Every species of plant flourishes best within a certain range of temperature, beyond which, on both sides, it either suffers from summer heat or is killed by winter cold.

910. If the earth's surface were of uniform character, we might expect to find forms of vegetation arranged in bands or zones succeeding each other from the equator toward the poles, each occupied by plants "hardier" than those of its equatorial neighbour. Such zones of vegetation have in fact been laid down by botanical geographers. Meyen drew up a plan, in which a number of zones were marked down, defined on each side by lines passing round the earth at certain parallels of latitude, between which a certain average climate was assumed to exist.

But, from the want of uniformity of the surface of the globe, the *isothermal lines, i. e.* lines passing through spots which have an equal annual temperature, by no means correspond to parallels of latitude—the distribution of land and sea, and the alternation of plains and mountains, deflecting such lines to the north and south, sometimes to a very great extent. In addition to this, from the diversity of habit of plants, they are differently affected by heat and cold, and the distribution of species is far more influenced by the *summer* and *winter* temperature than by the entire amount of heat received during the year.

Nevertheless, as a general rule, plants have a *polar* and an *equatorial* limit, fixed by temperature.

Temperature as regards plants may be divided into useful, useless, and injurious or destructive. Each plant requires a certain sum of heat to live, so much more to flower, more still to ripen its fruit, &c. Within certain limits it is immaterial whether the plant get this heat in a short period or diffused over a longer time. Temperatures below 32° F. are useless to most plants (that is to say, vegetative action is arrested); but many survive at a much lower temperature. Every plant has a zero of its own.

911. An important qualification arises from the existence of high mountains within temperate and tropical latitudes. The temperature of the soil and atmosphere diminishes with the degree of elevation above the surface of the ocean; and a succession of limits are found upon the sides of high mountains comparable, and in a great degree proportional, to the polar and equatorial limits of plants. Mountains situated in the tropics possess zones of climate which, at successive elevations, resemble horizontal zones situated between the base of the mountains and the poles.

912. Moisture and drought are only to be called secondary climatal influences, from the circumstance that they depend in a great measure upon temperature, either directly or indirectly. In the Arctic regions and upon mountain-tops, covered with eternal snow, there is drought from the solidification of the water. In temperate and tropical regions the degree of humidity is dependent not merely upon temperature, but upon this combined with the configuration of the surface of the earth and the nature of the soils. Wherever the temperature of the atmosphere is above the freezing-point of water, it takes up aqueous vapour: even ice evaporates in warm air; and water evaporates in proportion to the temperature to which it is exposed.

The ocean, especially in warm latitudes, gives up vast quantities of aqueous vapour to the atmosphere, which it delivers in very various ways to the land regions. Islands and coasts in general have a moist climate, while the interior of continents is dry; but these rules are interfered with by currents or prevailing winds, carrying air loaded with moisture in particular directions. As an example of this, we find the west coast of Europe with a much damper climate than the opposite east coast of America, owing to the Gulf-stream and the winds bringing the moisture of the West-Indian Sea in a north-west current on to our coast. On the contrary, the prevailing winds blow off the west coast of North Africa, and those received on the north-east side come from over dry land, whence a vast tract of land lying in this continent becomes an arid desert.

There is a great difference also between mountainous and flat countries. The cold upper regions of tropical mountains arrest the prevailing currents of air and precipitate the moisture which they contain. Hence the tracts at the foot of mountains are well supplied with moisture if the altitude is sufficient, as at the south slope of the Himalayas and the east slope of the Andes. Ætna, which does not reach the line of perpetual snow in Europe, has arid and barren slopes in the upper regions.

These very general indications of climatal influence must suffice here to show how importantly vegetation is affected by physical influences.

A complete account of this branch of the subject would require a volume for itself.

913. Of all the influences to which plants are exposed, climate is the most important; it sets absolute limits to species, which is not the case with any other of the causes affecting distribution.

### *Secondary Natural Influences.*

914. There is no doubt that the distribution of plants is greatly affected by the conveyance of seeds, fruits, &c. from place to place within the same climatal region, by marine currents, rivers, winds, &c., and by animals, especially birds.

An example of diffusion by marine currents is furnished by the occurrence of the Cocoa-nut Palm fringing the islands of the Pacific; and it is probable that the mixed vegetation of many islands is to be accounted for in part by such causes. Marine currents are of most importance when they pass along coasts, or across tracts of ocean in similar latitudes—such as that part of the Gulf-stream running in the Mexican Gulf, the currents running from Madeira to the Canaries, from the last to Senegal, the east-to-west current of the Society Islands, &c. Rivers will also be most influential when they flow from the east or west. Currents of any kind passing northwards or southwards are less likely to convey seeds &c. into a suitable climate for their naturalization.

The winds do not appear to be very influential in transporting Phanerogamous plants; but the cosmopolitan distribution of the Cryptogamia is at least partially attributable to the facility with which their microscopic spores are carried away by currents of air.

Icebergs probably have some share in diffusing plants, since they are often found loaded with masses of earth containing seeds, which they occasionally cast upon strange shores. There is reason to believe that this kind of influence was far more actively at work in North Europe in the geological period preceding the present.

The transport by animals takes place partly through migrating birds, partly by quadrupeds which have wandering habits. Among birds, many of the omnivorous kinds (for instance the Thrushes) migrate from north to south in autumn, at the time when berries and similar fruits are ripe, and they often void the seeds of these fruits little altered. Animals which, like the northern Reindeers and the Buffaloes &c. of other lands, travel from place to place in troops in search of food, doubtless often carry seeds and fruits adhering to their fur into new localities. Flocks of animals transported through human agency become more fruitful sources of this influence.

915. Animals may likewise greatly affect vegetation in the way of limitation. The invasion of a region by flocks of graminivorous quadrupeds, the sudden appearance of plagues of locusts or any other of the numerous insect enemies of vegetable life, may quite change the character of the vegetation of a district, somewhat in the manner in which a totally different assemblage of plants springs up

on the ground cleared by burning the primæval forests of South America.

### *Effects of Human Interference.*

916. The results of the activity of man display themselves in both extensions and limitations of the distribution of species.

From the time of the earliest migrations of the human race, certain plants must have been in a condition of constantly increasing diffusion. The native countries of our Cereal grains are not satisfactorily known: they have been or are cultivated wherever they will grow in Europe and the adjoining parts of the other continents. Doubtless many of what we call weeds have shared in the transport of the seeds of useful plants, having been either mixed with them or accidentally adherent to the clothes, goods, or domesticated animals of the wandering races.

Transport of this kind would be still more active as agriculture extended; and wars, the improvement of navigation, the discovery of the New World, and countless minor events contributed to increase the interchange of the natural products of different regions, either intentionally or by accident.

Systematic cultivation of land is peculiarly favourable to the intermixture of new elements in the floras of particular regions, from the fact that *seeds* of many *varieties* of useful plants are constantly imported from climates where they ripen better or can be kept more easily at a higher standard of excellence.

Clover-seed, for instance, is largely imported into Britain from France and Germany; many of the weeds of our arable lands have doubtless been introduced with foreign seed, such as *Adonis autumnalis*, *Veronica Buxbaumii*, *Papaver somniferum*, &c. Ballast-heaps at sea-ports, where vessels returning home from foreign countries discharge their ballast, have become frequent sources of new importations; and merchandise, such as cotton, but especially seeds, fruits, dye-stuffs, &c., often contains seeds of plants, some of which now and then acquire a footing.

Horticulture is so evidently one of the most important influences in the diffusion of plants, that it is scarcely requisite to dwell upon it.

918. On the other hand, human industry has a great tendency to exterminate particular forms of vegetation, or, at least, to greatly affect their relative predominance in a given region. The destruction of forests for the purpose of clearing land for cultivation changes the whole face of vegetation, and even, to some extent, affects the local climate.

Instances of change of this kind might be furnished from almost every part of the globe. North Europe was clothed in early times of the present period with dense forests, long since cleared away to give place to cultivated plants and a multitude of wild plants suited to the different conditions of the soil. The forests of North America are, in like manner, disappearing by degrees under the hand of man.

The change is not merely one kept up by a continual effort of cultivation; the original vegetation does not always reestablish itself when the region is deserted. New kinds of plants spread over the cleared ground and new animal inhabitants come to check the efforts of the old forests to renew themselves.

### Sect. 2. INFLUENCE OF THE LAWS OF DEVELOPMENT OF PLANTS.

919. If we leave out of view the question of the origin or creation of plants, there is no reason why any given species should not exist in all places where the climate is suitable.

Some kinds of plants are, indeed, very widely spread over the surface of the globe. Dr. Hooker has enumerated upwards of 30 species of Flowering plants common to Northern Europe and the Antarctic regions. A considerable number of North-European species extend round the globe in northern latitudes, in the colder parts of North America and Asia. Not a few of our plants occur also on the Himalayan Mountains. *Epilobium tetragonum*, a British species, is found in Canada and in Tierra del Fuego. Our white Hedge-Convolvulus, with some other British plants, occurs in the Galapagos Islands. Many of the Falkland-Island plants are met with also in Iceland. *Plantago maritima*, a common sea-side plant with us, is found at the Cape of Good Hope and at the southern extremity of America.

920. Instances, however, of such cosmopolitan plants are exceptions to the rule, and the majority of the plants occurring over wide extents of the globe present characters which facilitate their diffusion by natural or artificial influences.

The plants (Phanerogamia) occupying even one-third of the earth's surface are but a small fraction of known plants. Many of these are aquatic or subaquatic plants; and a considerable number belong to the list of weeds which accompany man, growing in cultivated land or rubbish &c.; few or no woody plants occur in the lists hitherto published.

921. It is observable that those cosmopolitan species which occur widely spread over two continents are found also in the adjacent islands.

The arctic plants occurring in the continents of the Old and New World are found also in the Faroes, Iceland, and the Aleutian Islands.

922. On the other hand, certain plants occur only within very narrow limits; this is the case with many continental species, but more particularly with insular plants.

St. Helena, Kerguelen's Island, Tristan d'Acunha, Madeira, &c. have, or once had, peculiar species; the archipelagos of the Canaries and the Galapagos have species peculiar even to particular islands; California, the Cape of Good Hope, certain regions of the Andes, &c. possess species strictly limited to those regions.

923. The floras of many islands which possess peculiar species

include, besides, a greater number of species common to the islands and the nearest continents, or other islands, or both.

Of 672 species of Phanerogamia and Ferns occurring in Madeira, 85 only are peculiar, and 480 occur also in Europe. The Azores have 280 out of 425 in common with Madeira. The Canaries and Madeira have 312 species in common, Madeira and Gibraltar 170 in common. Great Britain has no species of Flowering plant peculiar to it: some of its plants are common in Central Europe, others in Western Europe; others, again, extend through the Färoes, Iceland, North Europe, and North Asia and America.

924. Generally speaking, the species of plants of a continent are found most abundantly over a particular more or less extensive tract, growing scarcer, more or less suddenly, at the margins of this space. Such a space, called the *area* of distribution of the species, in these cases exhibits a *centre* or point of greatest intensity of occurrence.

925. The areas of many plants extend not only over continents, but over detached islands, and even to other continents. In many instances species are spread interruptedly over their area, as is the case with the alpine plants common to Norway, Scotland, and the Alps, &c.

926. It is usual to find the maximum of a species in one country, forming a single centre; and this same species does not recur again with a centre in a distant spot with a similar climate and soil. But *representative species* of the same genus occur not unfrequently under such circumstances; and this is still more the case with genera of particular Orders, sometimes also with Orders of like habit.

Thus, the Violets of Europe and those of North America are distinct; the dwarf Palm, *Chamærops humilis*, of Europe, is represented by *C. Palmetto* in North America. The Heaths (*Erica*) of Europe are represented by different species at the Cape of Good Hope. The East and West Indies and Africa have their peculiar Palmaceæ, Zingiberaceæ, Marantaceæ, &c. The succulent Cactaceæ of Central America represent the fleshy Euphorbiaceæ, Asclepiadaceæ, and Mesembryanthaceæ of Africa. The Cape Heaths are represented in Australia by Epacridaceæ, associated in like manner with Myrtaceæ and Proteaceæ. The Firs of the southern hemisphere belong to genera distinct from those of the northern hemisphere, &c.

927. The evident absence of a constant relation between the existence of certain climatal conditions, and the occurrence of particular species of plants—still more, the existence of limited *areas* of distribution, often exhibiting *centres* of greatest abundance—have led to the supposition that the individual species of plants have been created at particular centres, whence they have spread themselves over more or less extensive tracts, in the course of their extension becoming intermixed with other species, and thus producing complex assemblages.

The spreading of what are called social plants, such as pasture-Grasses, Furze, various forest-trees, &c., illustrates the facility with which many plants extend themselves over new ground. The *Anacharis*, a North-American water-plant, has been diffused all over England within the last ten years. The diffusion of certain plants is also greatly dependent on the success of some plants over others in the struggle for existence which is ever going on in nature. It does not follow that the wild plants in any given area are those which are best adapted for that situation. They are often the weakest, and are overpowered by other plants. In this way native vegetation constantly gets exterminated by foreign intruders.

928. In this hypothesis, it is unimportant whether we imagine a single plant (or pair of diœcious plants) or a more or less extensive assemblage of individuals to have been created on the same spot. This is a question impossible to be solved by science.

Some authors believe that species have been created at many points where the conditions were fitting, explaining in this way the interrupted areas of certain plants.

929. The facts revealed by Geology, as well as by Botany itself, tend to prove that the creation of species has been not simultaneous, but *successive*, in different geological periods. Not only do we find fossil plants different from living vegetation in the older formations, but those beds immediately preceding the present surface of the earth contain not only remains of animals of existing species, but fossil plants closely resembling, if not identical with, existing plants.

930. Numerous cases of scattered distribution of existing vegetation cannot be explained by reference to existing influences, such as transport &c. (§§ 914, 916). Thus species with large seeds grow in countries between which exist apparently insuperable obstructions to transport; many species are common solely to the tops of very distant mountains; many widely distributed aquatic plants produce seeds which sink to the bottom of the water when ripe, &c.

Again, species are wanting in regions so well adapted to their existence that, when artificially introduced, they establish themselves like natives. Certain countries, separated by broad oceans, have more species in common than either the distance or nature of their climate would render probable under ordinary circumstances; while contiguous countries, with similar climates, sometimes present very different species.

Some countries are remarkable for a great number of species in a given area, others for paucity of species.

Lastly, species of simple structure (Rushes, Grasses, &c.) have often wide range, even though their seeds are not more easy of transport than usual, while others of higher organization, with seeds or fruits easily transported (Compositæ &c.), often occur in very limited areas.

931. To sum up these statements, the occurrence of each species,

as a general rule, in one region rather than another, their abundance in particular localities, the extension and especially the disjunction of species destitute of efficient means of transport, the non-extension, on the contrary, of species possessing seeds easy of transport, certain analogies and certain differences between the floras of several countries, and their relative richness in distinct forms—all these important phenomena are inexplicable by causes now in active operation; and we are consequently led to seek their solution by the aid of geological inquiries.

Edward Forbes was the first to open this line of inquiry, in a most acute and ingenious Essay on the Origin of the existing Flora of Britain. Dr. Hooker has pursued the same line of reasoning in his inquiries into the botanical geography of the southern hemisphere.

## Sect. 3. Geological Influences.

932. Natural Science is incapable of elucidating the actual origin or creation of organic beings; but it seeks to trace up, as nearly as possible, to the earliest periods the phenomena exhibited by created things or beings; and the botanist seeks, by geographical and geological inquiries, to discover the probable aboriginal localities of species of plants.

It is impossible to say in what part of the globe plants first appeared. Probably they grew on lands now submerged beneath the ocean, or, still more likely, they were perishable aquatic plants which have left no trace of their existence. Geology teaches that the dry land of the globe has been successively elevated and depressed below the surface of the sea at various epochs since plants were first created; hence there have existed successive and variable centres of creation. There may have existed means of communication between different centres, so that species may have passed over from one to another, and in this way survived in a new locality the destruction of their birthplace.

933. Species have made their appearance successively during different geological epochs, and have had more or less extended duration.

Probably most of our existing species date from an epoch anterior to that at which the existing continents acquired their present configuration.

They may have spread widely in ancient times, and their area may have been broken up subsequently by obstacles now insurmountable. They may have been transported in past ages by causes not now in operation.

Thus the disjunction of certain alpine and arctic species, that of aquatic or marsh-plants in distant countries, that of large-seeded plants in islands and more or less distant continents, may be explained by their antiquity or former wide diffusion, as well as by supposing creation at various points.

934. The species at present confined within small areas, in spite of means of transport or continuity of land and suitable climate, would appear to be those of most recent creation; that is, they seem to have originated since the existing continents were formed. Widely spread species which are difficult of transport are probably the most ancient.

935. In the comparison of successive geological formations, it appears that the earliest plants were chiefly species of simple organization and few in number—and that by degrees more highly organized plants were added and replaced many of the earlier ones, which perished. In existing vegetation the simpler kinds seem to be the most ancient, and those of more complex structure more recent, judging from the wider diffusion of the former than the latter.

Ligneous plants established themselves in northern and temperate countries at an epoch when the climate must have been more humid and more cloudy than at present. At the present time, regions in the South of Europe, North Africa, the Canaries, the Southern United States, and elsewhere, once cleared and exposed to the influence of the sun, do not become clothed again by forests such as thay possessed formerly. Coniferæ and Amentaceous plants, which form the chief constituents of forests in these regions, are Phanerogamia of low organization. Their probable antiquity, judging from their occurrence in masses in certain countries, confirms the view that existing species are of unequal antiquity, and that the older species are of lower type.

936. The facts of existing Botanical Geography are in general clear and concordant, if we suppose that the most ancient species of Phanerogamia are, first the majority of plants either aquatic or loving moisture, then many northern and alpine plants and most of the trees of our temperate regions—and if we suppose at the same time that the most recent species occur principally among the plants of warm regions, among the Dicotyledons with an inferior ovary and a monopetalous corolla (such as Compositæ, Dipsaceæ, Campanulaceæ &c.) and among the other Phanerogamia with structure complicated in other respects (such as Orchidaceæ, Palmaceæ, Apocynaceæ, Asclepiadaceæ, Cucurbitaceæ, Passifloraceæ, Begoniaceæ, &c.).

The considerations stated in this Section are derived, with slight modifications, from the 'Géographie Botanique' of Alph. De Candolle, a most important general work on this subject, which should be studied by all those who are interested in these questions.

# CHAPTER II.

## BOTANICAL GEOGRAPHY.

### Sect. 1. DISTRIBUTION OF PLANTS IN CLIMATAL ZONES BETWEEN THE EQUATOR AND THE POLES.

937. The description of the actual conditions of vegetation on the surface of the globe is a subject embracing a vast amount of facts, which are not only capable of being considered under many different points of view, but in many respects offer at present only fragmentary materials for establishing principles. In the present work, where only a limited space can be allotted to this department, it is necessary to confine ourselves to a few of the principal generalizations, calculated to give an insight into the characters of the study, but confessedly very imperfect as representations of the natural phenomena with which it deals.

938. In the preceding Chapter we have seen that climate has a most important influence upon vegetation; and proceeding on this ground, it is possible to divide the surface into climatal zones, within which a certain average character of vegetation exists. But mere temperature is but one of the influences; and it is evident that many diverse conditions must exist within such climatal zones, dependent upon the other influences above referred to (§§ 907–912). Hence, although the general views afforded by marking out climatal regions are useful to the beginner, it is necessary to bear in mind that they are essentially superficial. In Meyen's subdivision of the globe, the zones were defined by parallels of latitude; but the distribution of temperature, the chief agent here regarded, is so irrelative to the parallels, especially in the northern hemisphere, that we have modified them by *isothermal* lines obtained from Dove's maps. The isotherms selected are mostly annual temperatures; but in defining the Arctic regions it has appeared more natural to take the line indicating an equal temperature in the months of September and July.

939. In the following summary the names of Meyen's zones are retained; the peculiar limitation by isothermal lines is indicated for each zone.

#### 1. *The Equatorial Zone.*

This zone, as limited by us, comprehends but a comparatively small range in the New World, and is most developed in the Old, especially in Africa. On consulting an isothermal map, it will be observed also that the larger portion of it lies on the north side of the equator, since the preponderance of land in the northern hemisphere deflects the isothermal lines in this direction. The boundaries are the annual isotherms of 79°·3 Fahr. on each side of the equator; but it may be noticed that in

Africa, as well as in Hindostan, and in the Indian archipelago, there exist between these lines circumscribed regions in which the annual isotherms rise to 81°·5 Fahr.

The characteristics of this zone are marked by the extreme luxuriance of vegetation, from the great heat, together with the abundant moisture. The trunks of the trees attain enormous diameter; the flowers have most brilliant colours; and not only is the earth clothed most profusely with numberless forms of plants, but the trees are overgrown by Orchids, Aroids, Bromeliaceæ, and Ferns, and matted together by *Lianes*, or gigantic rope-like woody climbers; so that the *primæval forests* present such a dense mass of vegetation as to be almost impenetrable, even to the explorer who advances axe in hand. The Palms, the Banana tribe (Musaceæ), arborescent Grasses, Pandanus, Scitamineæ, and Orchideæ are very striking features; the Fig-trees of most varied kinds, the Silk-Cotton-trees (Bombaceæ) also abound both in the Old and New Worlds; the Cæsalpiniæ, Malpighiaceæ, Anacardiæ, Swieteniæ, Anoneæ, Bertholletiæ, and Lecythideæ especially mark the forests of America; the Sapindaceæ, Caryotæ, Artocarpi, Sterculiæ, Ebenaceæ, Meliaceæ, Laurineæ, &c. those of the Old World. In this zone also, in the Indian archipelago, occurs the most remarkable of the Rhizanths, the gigantic parasite *Rafflesia*, with its flowers 3 feet in diameter; while in America this is almost rivalled by the Victoria Water-lily, and the Aristolochias with their enormous helmet-like flowers—said, indeed, to be worn in sport as caps by the Indian boys.

Rich as the vegetation of this zone is in general, we find within the limits some of the poorest tracts upon the globe—namely, where water is wanting. The African desert and a portion of Arabia are the most striking examples; but the llanos of Venezuela are scarcely less parched and lifeless during the dry season, and in the rainy season present only grassy plains like the steppes of Central Asia. The poverty of these tracts is accounted for by their peculiar position, cutting them off from the influence of moist currents of air, their natural waterless condition being of course dependent on the geological changes which gave them their present configuration.

### 2. *The Tropical Zones.*

These extend, in the north and south hemispheres, from the boundaries of the equatorial zone, at the isotherms of 79°·3 Fahr., to the isotherms of 72°·5 Fahr. Taken altogether, the characteristics of these zones, as might be expected, are closely allied to those of the preceding. Rio de Janeiro and Canton are cited by Meyen as instances of this resemblance; Palms, Bananas, Canneæ, Meliaceæ, Anoneæ, and Sapindaceæ prevail (in humid districts) here, and Orchids, Pothos-like plants, and *Lianes* abound. The Tree-Ferns, the Pepper-plants, Melastomaceæ, and Convolvulaceæ, however, become more prominent here, and serve as distinctive characters; and it is stated that, in these zones, the forests exhibit fewer parasites and more underwood. That portion of the western coast of South America lying within the south tropical zone forms an exception to the general rule of luxuriance of vegetation, as does the inland tract of Africa bordering on the equatorial zone.

### 3. *The Subtropical Zones.*

These are bounded on the equatorial side by the annual isotherm of 72°·5 Fahr., and towards the poles by the isotherms of 68° Fahr. The countries lying within these enjoy the most delightful climates on the globe. Though the summer heat never rises to the intense heat of the torrid zone, it suffices to ripen most of the tropical fruits; while the winters are so mild that vegetation is never arrested. Palms and Bananas are still met with in the plains, and arborescent Grasses form a feature of the landscape, both in America and Asia; but the most striking character of these regions is formed by the abundance of forest trees having broad, leathery, and shining leaves, such as the Magnolias and the Lauraceæ, and also of the plants of the Myrtle tribe. Proteaceæ, Acacias, and Heaths attain their maximum development.

### 4. *The Warmer Temperate Zones.*

Equatorial boundaries, the annual isotherms of 68° Fahr.; polar boundaries, the isotherms of 54°·5 Fahr. The general characteristics of these zones arise from the combination of the shining, leathery-leaved trees of the subtropical zones with the forest trees which we find in our own country, such as Oaks, Beeches, &c.; the Palms vanish; but a number of handsome evergreen shrubs present themselves, and Heaths, Cisti, and showy Leguminous plants are very abundant. The countries lying within these zones in different parts of the globe differ a good deal in their vegetation, and we may therefore enter into rather more detail here.

In the Mediterranean region evergreen dicotyledonous trees with glossy leaves, showy shrubs, and many bright-coloured bulbous plants abound; *Erica arborea*, the Bay, and the Myrtle are characteristic; the Turkey, Holm, and Cork Oaks, the Chestnut, the Strawberry-tree, with the Cherry-Laurel, Laurustinus, and Pomegranate are frequent, as are also the Phillyreæ, Rosemary, Oleander, &c.

The Vine is a native of this zone, and is said to attain a diameter of 3 to 6 inches, and to climb to the top of the highest trees, in the forests of Mingrelia and Imeritia. The barren tableland of Asia falls in this zone, as does Japan, which has a rich vegetation. In America are found abundance of Oaks and Pines, Magnoliaceæ (such as the Tulip-tree), a number of Leguminous trees, with thorny Smilax-shrubs and gigantic Reeds; the Gleditschiæ on the banks of the Ohio are evergreen, with climbing Bignoniæ; evergreen trees here correspond to those of Southern Europe, intermingled in the forests with Oaks, Beeches, Ash, and *Platanus occidentalis.*

In the southern hemisphere this zone includes part of New Zealand and Australia, where, again, evergreen trees are intermixed with forest-trees with deciduous leaves; shrubby Ferns abound, and the Leguminosæ and Myrtaceæ are well represented.

In South America, the Pampas-plains of Buenos Ayres fall in this zone, especially characterized by arborescent Grasses. Southern Chili represents the warm temperate vegetation with its evergreen forests of Myrtaceæ, Beeches, and Araucarias; the Fuchsia is also characteristic of this region. The Chilian Palm, like the dwarf Palm of Southern Europe and the Palmetto of North America, forms an outlier from the subtropical region.

### 5. *The Cooler Temperate Zones.*

Equatorial boundaries, the annual isotherms of 54°·5 Fahr.; polar boundaries, the isotherms of 41° Fahr. The especial characteristics of these zones are the forests of deciduous trees with inconspicuous blossoms, intermingled with social Conifers, together with the Grass-pastures. Here the trunks of the trees are overgrown only with Mosses and Lichens; the Honeysuckle, the Ivy, and the Hop are the only important climbers, very different from the *Lianes* of the tropics. Shrubs are pretty frequent, but they mostly lose their leaves in winter, such as Roses, Brambles, Viburna, &c. The social Dwarf-grasses on good soil, with the Sedges, Cotton-grasses, and Mosses of wet ground, characterize the plains, and extensive heaths prevail in some districts. The contrast between summer and winter is strongly marked in the aspect of vegetable life: the trees are stripped of their leaves, the herbs die down to dwarf tufts, or hide themselves altogether in the ground, and the snow covers the surface of the plains in severe weather; but the warmth of summer, which brings out a lively and varied show of flowers, is sufficiently high to ripen the seeds of many, and thus annuals are more numerous than they are further north.

This zone is not represented in Africa or in the South Sea. In South America it includes Patagonia.

### 6. *The Subarctic Zone.*

Equatorial boundary, the annual isothermal line of 41° Fahr.; polar boundary, the isotherm of 36°·5 Fahr. for the month of September. The southern boundary of this zone in the northern hemisphere corresponds pretty nearly to the limit of distribution of the Oak in Europe and the east coast of North America, the northern boundary to the limit of the distribution of trees.

The striking characteristic of this zone is, indeed, the predominance of the Coniferous trees in the woods, giving place northward to the Birch and Alder, and generally alternating with Willows where the soil is moist. Green pastures occur universally, especially adorned with showy flowering herbs in the spring and summer.

### 7. *The Arctic Zone.*

The equatorial boundary is the isotherm of 36°·5 Fahr. for the month of September, or the polar limit of arborescent vegetation in the northern hemisphere; the polar boundary is the isotherm of 41° Fahr. for the month of July. The vegetation of this zone corresponds to what we understand commonly as Alpine shrubs, consisting chiefly of prostrate shrubs, with a peculiar tortuous and compact habit of growth, such as the alpine Rhododendra, Andromedæ, the dwarf Birch and Alder, the Bog-Myrtle and dwarf Willow, with a variety of low-growing perennial herbs, remarkable for the comparatively large size and bright colour of their flowers. Sedges and Cotton-grasses occur socially, in some places covering extensive tracts; but the grassy pastures of the last zones are replaced to a great extent by tracts covered with Lichens.

### 8. *The Polar Zone.*

Equatorial boundary, the isotherm of 41° Fahr. for the month of July; polar limit, the isotherm of 36°·5 Fahr. for the same month. This zone is characterized by presenting, in the four to six weeks of summer, an alpine vegetation devoid of even shrubs, and consisting of herbaceous perennials of dwarf habit, such as Saxifrages, Ranunculi, Pyrolæ, Potentillæ, Dryas, Draba, &c., and possessing, moreover, certain genera (such as Parrya, Phippsia, and others) which, although they extend into the arctic zone, are not met with in the alpine regions of the mountains of the more southern regions. In Spitzbergen, the number of Cryptogamic plants is remarkable, the Lichens alone equalling the Flowering plants, and predominating even in mass as well as number of species.

## **Sect. 2.** REGIONS OF ALTITUDE.

940. It is well known that the lofty mountains lying within the tropics exhibit a graduated variation of character in their vegetation, and that those which rise above the limit of eternal snow display more or less distinctly marked regions, representing the zones lying between the plains at the foot of such mountains, and the eternal ice of the polar zone.

Humboldt divided the surface of tropical mountains into three zones, representing the tropical, temperate, and frigid zones of the globe, and indicated the principal subdivisions of these regions. Meyen attempted to lay down a more systematic representation of the conditions in question, corresponding to his division of the earth's surface into zones. Great difficulty interposes here in any attempt at generalization, since local conditions, arising from aspect, and conformation of surface, either giving more or less of precipitous character, accompanied by sudden changes, or producing elevated plains, &c., cause such great differences, even within the limits of single mountain-systems, that no absolute rule can be applied. The rules laid down by Meyen apply pretty well to his zones within the limits of Europe; but, in the delineation of the regions of altitude of greater extent, great variation presents itself near the equator.

941. According to Meyen's views, the snow-line, beginning at the polar zone, rises between 1900 and 2000 feet above the level of the sea, and in the equatorial zone to 15,500 or 16,600 feet; and he divides the regions of altitude in accordance with this, raising each region between 1900 and 2000 feet in each zone, as he approaches the equator. Now at North Cape, which lies near the polar limit of our subarctic zone, and in Iceland, which is crossed by the same limit, the line of perpetual snow is at about 2000 feet; we may therefore take this as the snow-line of the *arctic zone*. The equatorial limit of the subarctic zone falls in Southern Norway, where the snow-line is at about 4000 feet; while the equatorial limit of our cold temperate

zone is not far removed from the Alps and Pyrenees, where the snow-line rises to 8000 feet and more. In the south of Spain, lying within the warm temperate region, snow lies in isolated patches below 11,000 feet. In the district of Sierra Nevada, which is one of the best-known of the mountains of this zone, as regards vegetation, there is a subtropical region up to 600 feet, the true warm temperate vegetation extends up to about 4000 feet, a cold temperate vegetation from about 4000 to 6500; the vegetation then passes into a condition allied to the subarctic, but without trees, and characterized by shrubs of a similar nature to those of the arctic zone. This region extends to 8000 feet; and thence to the summits of 11,000 feet there is an alpine summer vegetation (snow lying for eight months out of the twelve), which, again, is intermediate in character between those of the arctic and polar, consisting chiefly of perennial herbs like the latter, but presenting a formation of turfy pasture to some extent in the warm season. In the Caucasus the snow-line is much higher.

In the subtropical zone, on the Peak of Teneriffe, we find the vegetation of the warm temperate zone from about 2000 to 4000 feet, a representation of the cold temperature from 3000 to over 6000 feet; at about 8000 feet the climate is subarctic. This mountain does not reach the snow-line.

In Mexico, lying in our tropical zone, the lines are respectively shifted up in about the same ratio. We see throughout, then, a deviation from Meyen's ratio, in the tendency of the colder zones to widen out on the mountains of warmer zones; but this is partly owing to our dividing the zones according to temperature, and not according to latitude.

If we attempt to lay down the conditions of the mountains of Asia under a similar point of view, we find greater deviations. The mass of elevated land in Central Asia modifies all the climatal conditions very much. The snow-lines of the mountains of the cold-temperate and warm-temperate zones rise to 14,000 feet; that of the Himalayas to 18,000 feet in the northern parts. Our data scarcely suffice for the illustration of these modified conditions and therefore we have confined ourselves to a limited number of the best-explored mountain-regions of the Old and New Worlds, in the tabular view of distribution in altitude given below.

9 2. We now give a brief sketch of the characteristics of the different regions of altitude, as classified by Meyen; and to this is subjoined Meyen's hypothetical table, from his 'Geography of Plants.' To show how far this diverges from the actual conditions, we subjoin Tables, constructed for Johnston's 'Physical Atlas,' showing the comparative altitudes of the characteristic forms of vegetation on a number of mountains where they have been carefully observed. The location of these mountains in the various zones is in accordance

with our isothermal limitation, and not, as is the case with Meyen's limitation, according to parallels of latitude. The elevations are also merely given given in round numbers.

### 1. *Region of Palms and Bananas.*

Corresponding to the equatorial zone, and has been already characterized under that head.

### 2. *Region of Tree-Ferns and Figs.*

Corresponding to the tropical zone. The genus Ficus is most prevalent in the elevated forests of the equatorial zone of the East Indies, giving them a remarkable character of gloomy grandeur and impervious density.

### 3. *Region of Laurels and Myrtles.*

Corresponding to the subtropical zone.

### 4. *Region of Evergreen Trees.*

Corresponding to the warm temperate zone.

### 5. *Region of Deciduous Trees.*

Corresponding to the cold temperate zone; but this region seems to be absent from the mountains in many parts of the tropical and equatorial zones, since the tree-limit is carried down by peculiarities of climate, which, on the other hand, favour the advance of more southern forms into the upper regions. In Java and Sumatra, stunted trees of the class belonging here replace the dwarf Conifers of European mountains, and form the tree-limit far below the altitude at which forests of tall Conifers occur in the more northern Himalayas,—a condition explained in some degree by the local circumstances of the equatorial mountains, which are deficient of the supplies of moisture furnished by the vast masses of snow resting perpetually upon the Himalayas.

### 6. *Region of Conifers.*

Corresponding to the subarctic zone. This zone, characterized by the growth of Pines and Firs, is well represented on most mountains, with the exception of the Peruvian Cordilleras, where the Escalloniеæ are said to be substituted for them. But the Conifers do not always form the uppermost belt of trees, even when they flourish in a well-defined region. Thus the region of the Conifers, in a general sense, which reaches to the tree-limit with Pines in the Alps, Pyrenees, and the Andes of Mexico, includes, in the Scandinavian mountains, in the Himalayas, and the Caucasus, a region of Birches, which rise out of it to form the last representatives of arboreal vegetation.

### 7. *Region of Alpine Shrubs or of Rhododendra.*

This region corresponds to the arctic zone. In the Himalayas, dwarf Willows, Junipers, and species of Ribes or Currant seem to represent the vegetation of this region; while on the Andes of Quito the genus Befaria appears to correspond in its geographical development to the Rhododendra of the north.

### 8. *Region of Alpine Herbs.*

Corresponding to the polar zone, usually presenting only patches of vegetation scattered over a broken surface of ground, covered during the greater part of the year with snow, and exhibiting accumulations in all seasons in sheltered spots. Lichens abound here; *Lecidea geographica* has been found in most diverse localities where bare rock rises above the ground, forming generally the last trace of vegetation. The plants of this region are remarkable in many respects, in none more than the beauty and comparatively large size that usually characterizes their flowers. They are mostly of perennial growth, since, although the severe cold prevailing throughout the greater part of the year is unfavourable to the maturation and preservation of seeds, the thick covering of snow protects established plants from the severe frost; and it is known that they are arrested in warmer regions where winter frosts prevail without great accumulations of snow, precisely because they are then incapable of bearing the cold, to which they are directly exposed.

## MEYEN'S COMPARATIVE EXHIBITION OF THE DIFFERENT ZONES, WITH THE CORRESPONDING REGIONS.

*The elevations and temperatures are here given in round numbers.*

| Distance of the Regions from the Plain. | Names of the Zones......... | Equatorial. | Tropical. | Sub-tropical. | Warm Temperate | Cold Temperate | Subarctic. | Arctic. | Polar. | Distance from the Snow-line. | Mean Annual Temperature of the Regions (by Fahr. Scale). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Areas of the Zones ...... | Lat. 0°–15° | 15°–23° | 23°–34° | 34°–45° | 45°–58° | 58°–66° | 66°–72° | 72°–82° | | |
| | Mean Heat ... (in deg. Fahr.). | 79°–86 | 73½°–79° | 64½°–70° | 54°–57° | 43°–54° | 36°–43° | 32°–28½° | 28½° and under. | | |
| 16,000 | | 16,000 | 14,000 | 12,000 | 10,000 | 8,000 | 6,000 | 4,000 | 2,000 | | |
| 14,000 | Region of Alpine Herbs. | | 12,000 | 10,000 | 8,000 | 6,000 | 4,000 | 2,000 | | 2,000 | 37½°–39½° |
| 12,000 | Region of Rhododendra. | | 10,000 | 8,000 | 6,000 | 4,000 | 2,000 | | ...... | 4,000 | 41½° |
| 10,000 | Region of Coniferæ. | | 8,000 | 6,000 | 4,000 | 2,000 | | ...... | ...... | 6,000 | 52° |
| 8,000 | Region of Deciduous Dicotyledonous Trees. | | 6,000 | 4,000 | 2,000 | | ...... | ...... | ...... | 8,000 | 57° |
| 6,000 | Region of Evergreen Dicotyledonous Trees. | | 4,000 | 2,000 | | ...... | ...... | ...... | ...... | 10,000 | 63° |
| 4,000 | Region of Myrtles and Laurels. | | 2,000 | | ...... | ...... | ...... | ...... | ...... | 12,000 | 68°–70° |
| 2,000 | Region of Tree-Ferns and Figs. | | | ...... | ...... | ...... | ...... | ...... | ...... | 14,000 | 72°–77° |
| 0 | Region of Palms and Bananas. | | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 16,000 | 81°–86° |

COMPARISON OF REGIONS OF ALTITUDE WITH ISOTHERMAL ZONES.

*The figures indicate the elevations at which the regions commence.*

| **Names of Zones . . .** | **Equatorial Zone.** | **Tropical Zone.** | | **Subtropical Zone.** | |
|---|---|---|---|---|---|
| **Temperature of Zones .** | 81° 5′ to 79° 3′ Ann. Mean. | 79° 3′ to 75° 5′ Ann. Mean. | | 72° 5′ to 68° Ann. Mean. | |
| **Names of Mountains . .** | Java and Sumatra. | Andes of Mexico. | Andes of Peru. | Teneriffe. | Himalayas. |
| **Snow-line . .** | None. | 15,500 | 15,500 | None. | 15,000—18,000 |
| **Alpine Herbs.** | 9,0000<br>Viola, Ranunculus, Myrica, Erica. | 13,600 | Primulaceæ, Ranunculaceæ, Rosaceæ, &c. Berberis. | 10,400 | Papaveraceæ, Cruciferæ, Primulaceæ, &c. |
| **Alpine Shrubs** (Rhododendra, &c.) | 7,000 | Steviæ. 11,000 | Befariæ. 10,400 | 9,000 | Salix, Spiræa, Juniperus, Lonicera. 14,000 |
| **Limit of Trees.** | | | | | |
| **Conifers and Birches.** | Podocarpus. | Abies religiosa, &c. 8,000 | Escalloniæ. 8,900 | Juniperus Oxycedrus. 6,000 Spartium. | Abies, Pinus. |
| **Deciduous Forest Trees** (Oak and Beech). | | Quercus. 6,000 | | Pinus canariensis. 4,000 | Quercus. 10,000 |
| **Evergreen Forest Trees.** | Ternstrœmiaceæ.<br>6,000 | Melastoma, Yucca, Bambusa. | | Ardisia, Laurus. 2,500 Olea, Myrica. | Magnolia, Castanea. 7,000 Ardisia. 6,000 |
| **Lauraceæ and Myrtaceæ.** | Dipteraceæ.<br>4,000 | Jatropha, Chamædoreæ, Malpighiaceæ, &c. | Cacti, Eugenia. 5,000 Cinchonæ, Melastomeæ. | 1,200 Arborescent Euphorbiæ, Dracæna, Ficus Sycamorus. | Celastrus, Gumbelia, Myrsine. 3,000 |
| **Tree-Ferns and Figs.** | Forests of Liquidambar.<br>2,000 | Tropical Forests.<br>3,000 | Tree-Ferns, &c.<br>3,000 | Bananas, Saccharum, Palms. | Tree-Ferns, Figs, Palms. |
| **Palms and Bananas.** | Palms, Scitamineæ, Damp Equatorial Forests. | Bombax, Palmæ, Mimoseæ. | Palmæ, Scitamineæ. | 29° N. L. | 28°—36° N. L. |
| **Sea-level.** | 0°—10° S. L. | 19° N. L. | 0° | | |

### COMPARISON OF REGIONS OF ALTITUDE WITH ISOTHERMAL ZONES.

| Name of Zone . | ..............Warm Temperate Zone. | | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature of Zone .. | ..........................63°·5 to 54°·5 Annual Mean. | | | | | | |
| Names of Mountains. | Rocky Mountains. N. America. | Sierra Nevada, Spain. | Lycian Taurus. | Pontic Chain of Lasistan. | Ararat. | Inner Armenia. | Alatau, Soongarei. |
| Snow-line. | 11,800 | None. | None. | 10,000 | 13,500 | 11,000 | 10,700 |
| Alpine Herbs. | | 11,000<br>Alpine Herbs and Shrubs.<br>7,000 | 10,000<br>Alpine Herbs and Shrubs.<br>8,000 | 8,000 | | | Lichens. 8,000 |
| Alpine Shrubs, &c. | 11,000 | | | Rhododendron caucasicum. 5,700 | 8,000 | 5,600 | Junipers 7,500 |
| Limit of Trees. | | | | | | | |
| Conifers and Birches. | Pinus. | Pinus sylvestris. 4,500 | Juniperus excelsa. 6,000 | | | 4,500 | Pinus. |
| Deciduous Forest Trees. | | Quercus retusus, Pinus Pinaster. 2,000 | Plateaux. 3,000<br>Oak Woods. 1,500 | Beech with Firs. 4,600 | | Beech. 1,000 | |
| Evergreen Forest Trees. | | Olive, Cork, Pomegranate 600 (Opuntia, Cotton, Sugar Cane.) | Evergreen Trees and Shrubs. | Evergreen Shrubs. | | Olea, Laurus, Buxus, Planera. | |
| Lauraceæ and Myrtaceæ. | 39° N. L. | 37° N. L. | 37° N. L. | 41° N. L. | 40° N. L. | 37° N. L. | 44°–46° N. L. |
| Sea-level. | | | | | | | |

### COMPARISON OF REGIONS OF ALTITUDE WITH ISOTHERMAL ZONES.

| Names of Zones. | Cold Temperate Zone. | Subarctic Zone. | | Arctic Zone. |
|---|---|---|---|---|
| Temperatures. | 54° 5′ to 41° Annual Mean. | 41° Ann. Mean to 36° Mean of Sept. | | 36° Mean of Sept. to 41° Mean of July. |
| Names of Mountains. | Swiss Alps. | Norway. | Kamtschatka. | Iceland. |
| Snow-line. | 8,500 | 4,000—5,000 | 5,000 | 2,000 |
| Alpine Herbs. | 7,000 | 3,300—3,800 | Saxifraga.<br>2,700 | 1,000 |
| Alpine Shrubs, &c. | 6,000 | Dwarf Birch, Willow.<br>2,000—3,000 | Alnus incana, Rhododendrons.<br>2,000 | Alpine Shrubs. |
| Limit of Trees. | | | | |
| Conifers and Birches. | Conifera.<br>4,000 | Birch.<br>1,000<br>Conifera.<br>2,000 | Alnus fruticosa, Sorbus, Coniferæ.<br>500 | 64° N. L. |
| Deciduous Forest Trees. | Beech and Oak.<br>2,000<br>Chestnut. | 67° N. L. | 60° N. L. | |
| Evergreen Forest Trees. | 46°–47° N. L. | | | |
| Sea-level. | | | | |

On comparing these Tables with Meyen's, by noticing the latitudes given at the foot of the columns, it will be seen that the location of the mountains in the various zones differs only in the hotter and colder of the latter; those of the warm temperate, cold temperate, and subarctic (except in the case of Iceland) being similarly arranged. The great discrepancies existing between mountains occurring in the same zone indicate that local circumstances must have most powerful influence in determining the altitudes attained by the various classes of vegetation. We are not in a position to give the real temperatures of regions of altitude with any accuracy in most cases; or these would probably greatly assist in ascertaining the direct causes of aberration; for differences of temperature certainly accompany the difference of elevation attained by particular forms of plants. Good examples of the influence of the form and local conditions of mountains are furnished by Teneriffe, Ararat, the Himalayas, and the Rocky Mountains of North America. The first is an isolated mountain, exposed to the equalizing influence of the ocean; the second an isolated mountain situated in the interior of a continent; the two chains are portions of enormous systems of mountains extending over large regions in the interior of continents. To work out this subject thoroughly, however, it is necessary to observe not only the conditions of different mountains, but those of the different declivities of the same mountain; since, when great elevations are attained, chains of mountains form the boundaries of local climates, and present different conditions on the two faces.

## Sect. 3. DIVISION OF THE GLOBE INTO REGIONS HAVING CHARACTERISTIC VEGETATION.

943. The character of the vegetation of different regions is influenced not merely by climate, but by the more remote causes referred to in the last Chapter, which have led to the distribution of plants over more or less extensive areas, and their restriction within narrow limits in other cases; further, by the habit of plants, as by a social mode of growth, by size, &c.

944. Many attempts have been made to divide the earth's surface into Botanical Regions, according to their characteristic vegetation. None of these can be regarded as satisfactory; but perhaps the generalizations of Schouw are, on the whole, those which suggest most to the student. We therefore introduce here that author's account of the 25 regions into which he divided the globe, on principles which are stated below.

These regions were characterized several years ago; and much has been discovered since, tending to modify the details; it is greatly to be desired that a new attempt should be made in this direction.

### *Schouw's Phyto-geographic Regions.*

945. The regions are founded on the following principles:—

1. At least one-half of the known species of plants of the tract constituting a botanical region are peculiar to it.

2. A fourth part of the genera of the region are either peculiar to it, or have so decided a maximum that they are comparatively rare in other regions.

3. The individual Orders of plants are either peculiar to the region or have a decided maximum there.

### 1. *Region of Mosses and Saxifrages (Arctic-Alpine, or Wahlenberg's Region).*

*Mean temperature.*—Polar regions, 2°–41° Fahr. Mountains in the south, 21°–37° Fahr.

*Character.*—*Characteristic and predominant genera*—Ranunculus, Arabis, Draba, Arenaria, Dryas, Potentilla, Saxifraga, Rhododendron, Azalea, Gentiana, Pedicularis, Salix, Musci, Lichenes. Of the polar countries especially—Coptis, Eutrema, Parrya, Diapensia, Andromeda, Ledum. Of the mountain regions—Cherleria, Campanula, Phyteuma, Primula, Aretia, Soldanella. Dwarf perennial herbs with comparatively large flowers of bright colours. Trees absent.

*Predominant shrubs and half-shrubs of the polar countries.*—Betula nana, Salix herbacea and other species, Rubus Chamæmorus, Empetrum nigrum, Andromeda hypnoides, A. tetragona, Arbutis alpina, A. Uva ursi, Azalea procumbens, Rhododendron lapponicum, Menziesia cærulea.

*Predominant shrubs and half-shrubs of the mountains.*—Juniperus nana, Alnus viridis, Salix reticulata, S. herbacea, Rhododendron ferrugineum, R. hirsutum, R. caucasicum, Vaccinium Myrtillus, V. uliginosum, Azalea procumbens, Arbutus alpina, A. Uva ursi, Empetrum nigrum.

*Plants which approach very closely to the snow-line.*—Ranunculus glacialis, Saxifraga oppositifolia, Silene acaulis; in the polar countries especially, Agrostis algida, Ranunculus hyperboreus, R. nivalis, Saxifraga rivularis, S. cernua, S. nivalis, Papaver nudicaule, Draba alpina, Lychnis apetala, Diapensia lapponica. In the mountain-regions, Saxifraga muscoides, S. bryoides, Cherleria sedoides, Aretia helvetica, A. alpina, Draba nivalis, Petrocallis pyrenaica, Arabis bellidifolia, Myosotis nana, Gentiana nivalis, Achillea nana, Linaria alpina. No cultivation in this region.

The flora, as a whole, as tabulated by Hooker, is decidedly Scandinavian. Some of its members are universally diffused throughout the globe, even in the tropics (on mountains); hence the Scandinavian flora is considered to be the oldest existing flora.

### 2. *Region of Umbelliferæ (North-European and North-Asiatic, or Linnæus's Region).*

*Mean temperature*, 29°–46° Fahr.

*Character.*—Umbelliferæ, Cruciferæ, Coniferæ, Amentaceæ, Graminaceæ, Cariceæ, Fungi, Cichoraceæ, Cynareæ; in Asia, more particularly, Saline plants (such as Salsola and Salicornia) and Astragaleæ. Luxuriant pasture; forest trees with deciduous leaves; a few Heaths.

*Predominant trees and shrubs.*—Pinus sylvestris, P. Cembra, P. sibirica, Abies excelsa, A. pectinata, Larix europæa, Juniperus communis, Betula alba, Alnus glutinosa, A. incana, Fagus sylvatica Quercus pedunculata, Q. sessiliflora, Carpinus Betulus, Castanea vesca, Salices, Populus tremula, Corylus Avellana, Ulmus campestris, Calluna vulgaris, Prunus spinosa, Pyrus Aucuparia, Acer Pseudo-platanus, A. platanoides, A. campestre, Tilia platyphylla, T. microphylla.

*Cultivated plants.*—Cereals: Rye, Barley, Oats, Wheat, Spelt, Maize, Millet (Panicum miliaceum), Buckwheat, Potato.

*Fruits.*—Apple, Pear, Quince, Cherries, Plums, Apricot, Peach, Mulberry, Walnut, Grape, Currant, Gooseberry, Strawberry, Melons.

*Esculent vegetables.*—Cabbage, Rape, Turnip, Radish, Mustard, Peas, Beans, Lentils, Spinach, Beet, Cucumber, Gourd, Carrot.

*Fodder-plants*, &c.—Clovers, Vetches, Lucerne, Rye-grass; Hops, Flax, Hemp, Tobacco.

### 3. *Region of the Labiatæ and Caryophylleæ (Mediterranean, or De Candolle's Region).*

*Mean temperature*, 55°–73° Fahr.

*Character.*—Labiatæ, Caryophylleæ, Boragineæ, Cistineæ, Liliaceæ; the Orders cited in the preceding region, but mostly less prevalent, especially the Cariceæ. Representatives of tropical Orders—Palmæ, Terebinthaceæ, Lauraceæ,—Orders which increase towards the equator becoming more numerous: Leguminosæ, Malvaceæ, Solanaceæ, Euphorbiaceæ, Urticaceæ.

*Genera.*—Adonis, Nigella, Trifolium, Medicago, Genista, Cytisus, Scabiosa, Anthemis, Achillea, Verbascum, Narcissus; many evergreen trees and shrubs; a greater number of woody plants than in the second region; pasture less luxuriant; a winter flora existing.

*Predominant trees and shrubs.*—Pinus Pinea, P. Pinaster, P. halepensis, P. Laricio, Cupressus sempervirens, Juniperus phœnicea, J. macrocarpa, Quercus Cerris, Q. pedunculata, Q. sessiliflora, Q. Ilex, Q. Suber, Q. Ægilops, Q. coccifera, Q. infectoria, Castanea vesca, Platanus orientalis, Alnus cordifolia, Corylus Colurna, Ostrya vulgaris, Acer monspessulanum, A. neapolitanum, Pistacia Lentiscus, P. Terebinthus, Ceratonia siliqua, Cercis siliquastrum, Genista scoparia, Mespilus pyracantha, Prunus laurocerasus, Tamarix gallica, T. africana, Myrtis communis, Punica Granatum, Opuntia vulgaris, Viburnum Tinus, Arbutus Unedo, Erica arborea, E. scoparia, Rhododendron ponticum, R. maximum, Cisti, Phyllyrea latifolia, P. angustifolia, Ornus europæa, O. rotundifolia, Nerium Oleander, Rosmarinus officinalis, Ephedra distachya, Chamærops humilis, Ruscus aculeatus, Smilax aspera, Tamus communis, Agave americana. (The highest parts of the mountains here belong to the first region, the middle elevations to the second region.)

*Cultivated plants.*—The same as in the preceding region; but the following are more rare, or only seen on the mountains: Rye, Currants, Gooseberry, Buckwheat, and Hop; while the following are added:—

*Cereals.*—Rice, Millets (Sorghum vulgare, Panicum italicum).

*Fruits.*—Figs, Almond, Pistachio-nut, Lemon, Citron, Sweet and Seville Oranges, Prickly Fig (Opuntia), Water-Melon, Olive.

*Esculents* &c.—Melongena, Tomato, Anise, Coriander, Cotton, White Mulberry, Saffron, Sumach, Lupins, Sainfoin.

*Note.*—Madeira, the Azores, and Canaries belong to this region; but their floras approach that of North Africa.

*Characteristic forms.*—Sempervivum arboreum, S. canariense, S. tortuosum, &c., Ilex Perado, Pleroma pendula, Cacalia Kleinia, Sonchus fruticosus, Arbutus callicarpa, Ardisia excelsa, Ceropegia aphylla, Echium giganteum, &c., Laurus fœtens, Euphorbia balsamifera, E. canariensis, Myrica Faya, Pinus canariensis.

### 4. *Region of Asteres and Solidagines* (*Northern North-American, or Michaux's Region*).

*Mean temperature*, 9°–59° Fahr.

*Character.*—More species of Coniferæ and Amentaceæ than in the second region), but fewer Umbelliferæ, Cruciferæ, Cichoraceæ, and Cynareæ.

*Genera.*—Hydrastis, Sanguinaria, Hudsonia, Ptelea, Robinia, Gymnocladus, Purshia, Gillenia, Decodon, Œnothera, Clarkia, Ludwigia, Bartonia, Claytonia, Heuchera, Itea, Hamamelis, Mitchella, Aster, Solidago, Liatris, Rudbeckia, Gaillardia, Vaccinium, Andromeda, Kalmea, Sabbatia, Houstonia, Hydrophyllum, Phlox, Monarda, Dodecatheon, Dirca, Hamiltonia, Lewisia, Trillium, Medeola.

*Predominant trees and shrubs.*—Pinus Strobus, P. inops, P. resinosa, P. Banksiana, P. variabilis, P. rigida, P. serotina, P. pungens, Abies balsamea, A. taxifolia, A. canadensis, A. nigra, A. rubra, A. alba, Larix pendula, L. macrocarpa, Thuja occidentalis, T. sphæroidea, Juniperus virginiana, J. Sabina, Taxus canadensis, Quercus, 25 sp., Fagus sylvatica, F. ferruginea, Castanea americana, C. pumila, Ostrya virginica, Carpinus americana, Corylus americana, C. rostrata, Alnus glutinosa, A. crispa, A. serrulata, Betula nigra, B. papyracea, &c., Salix, 27 sp., Populus balsamifera, P. monilifera, &c., Myrica cerifera, &c., Platanus occidentalis, Liquidambar styraciflua, Juglans nigra, J. cinerea, &c., Ulmus americana, &c., Nyssa aquatica, Fraxinus alba, F. nigra, &c., Ornus americana, Ribes floridum, R. aureum, &c., Vaccinium, 20 sp., Andromeda, 10 sp., Kalmia latifolia, K. angustifolia, K. glauca, Azalea viscosa, A. nitida, A. glauca, A. nudiflora, &c., Rhododendron maximum, Cornus florida, C. alba, C. canadensis, &c., Hamamelis virginiensis, Spiræa salicifolia, S. chamædrifolia, S. opulifolia, S. hypericifolia, &c., Gillenia trifoliata, Cratægus, sp., Cerasus pumila, C. nigra, &c., Purshia tridentata, Rubus, 20 sp., Pyrus sp., Robinia Pseud-acacia, R. hispida, Gymnocladus canadensis, Rhus typhina, R. glabra, R. venenata, R. toxicodendron, &c., Ptelea trifoliata, Ceanothus americanus, &c., Rhamnus alnifolius, &c., Ilex opaca, &c., Euonymus americanus, E. atropurpureus, Staphylea trifolia, Ampelopsis hederacea, Acer rubrum, A. dasycarpum, A. saccharinum, A. striatum, Negundo fraxinifolium, Xanthoxylum fraxineum, X. tricarpum, Tilia glabra, T. pubescens, Liriodendron tulipifera.

In the northern parts (to 50°–55° N. L.) no cultivation. South of this, the same plants as those cultivated on the second region, but Maize more extensively.

### 5. *Region of Magnoliæ* (*Southern North-American, or Pursh's Region*).

*Mean temperature*, 59°–73° Fahr.

*Character.*—A certain approximation to the tropical vegetation; Canneæ (Canna, Thalia), Palmæ (Chamærops), Yucca, Cycadeæ (Zamia), Laurus, Ipomæa, Bignonia, Asclepias, Cacteæ (Mammillaria, Opuntia), Rhexia, Passiflora, Cassia, Sapindus.

Few Labiatæ, Caryophylleæ, Umbelliferæ, Cichoraceæ, Geranieæ; few species of Aster or Solidago.

Trees with broad shining leaves and large flowers.

*Genera.*—Magnolia, Liriodendron, Illicium, Asimina, Dionæa, Pavia, Amorpha, Gleditschia, Baptisia, Petalostemon, Calycanthus, Œnothera, Claytonia, Rudbeckia, Liatris, Silphium, Kalmia, Houstonia, Frasera, Halesia, Dodecatheon.

*Predominant trees and shrubs.*—Magnolia grandiflora, M. glauca, &c., Illicium floridanum, I. parviflorum, Liriodendron Tulipifera, Asimina, sp., Pavia flava, P. macrostachya, &c., Amorpha fruticosa, &c., Gleditschia triacanthos, &c., Robinia viscosa, Cassia Tora, C. marilandica, &c., Acacia glandulosa, Calycanthus floridus, &c., Kalmia hirsuta, K. cuneata, Opuntia vulgaris, O. fragilis, O. missouriensis, Halesia tetraptera, H. diptera, Laurus Catesbyana, L. caroliniensis, L. Benzoin, L. Sassafras, &c., Juglans fraxinifolia, Carya aquatica, C. myristiciformis, Liquidambar styraciflua, Carpinus americanus, Castanea americana, C. pumila, Platanus occidentalis, Quercus, 25 sp., Taxodium distichum, Pinus Tæda, P. palustris, Zamia integrifolia, Yucca gloriosa, Y. aloifolia, &c., Chamærops Hystrix, C. Palmetto, C. serrulata.

*Cultivated plants.*—About the same as in the third region, with the exception of the Olive. Cultivation of Rice more extensive. In the southern parts some tropical plants, especially the Sugar-cane.

### 6. *Region of Camelliea and Celastrineæ (Chinese, Japanese, or Kæmpfer's Region).*

*Mean temperature*, 54°-68° Fahr.

*Character.*— ?

*Genera.*—Magnolia, Nandina, Eurya, Camellia, Thea, Celastrus, Ilex, Euonymus, Bumalda, Hovenia, Kerria, Spiræa, Gonocarpus, Lagerstrœmia, Aucuba, Bladhia, Doræna, Eleagnus, Polygonum, Pollia.

*Predominant trees and shrubs.*—Rhapis flabelliformis, Pinus sinensis, &c., Cunninghamia lanceolata, &c., Taxus nucifera, T. verticillata, Salisburia adiantifolia, Cryptomeria japonica, Cupressus pendula, Juniperus virginiana, Thuja orientalis, T. dolabrata, Quercus glabra, Q. glauca, Alnus japonica, Juglans nigra, Broussonetia papyrifera, Daphne odora, Laurus glauca, L. lucida, L. umbellata, L. pedunculata, Olea fragrans, Diospyros Kaki, Mespilus japonica, Sophora japonica, Acer japonicum, A. septemlobatum, A. palmatum, &c., Camellia japonica, C. Sasanqua.

*Cultivated plants.*—Rice, Wheat, Barley, Oats, Doura (Sorghum vulgare), Millet (Eleusine coracana), Buckwheat, Sago (Cycas revoluta), Taro (Arum or Caladium esculentum), Batatas, or Sweet Potato; various species of Pear, Apple, Crab, &c., Quince, Plum, Apricot, Peach, Medlar; many species of Citrus (Oranges, Shaddocks, &c.), Melons.

Tea, Rapes (Brassica sinensis), Radish, Cucumber, Conomon, Gourds, Water-Melon, Anise, Star-Anise, Soja, Nelumbium, Trapa, Scirpus tuberosus, Convolvulus reptans, Beans, Peas, Solanum æthiopicum, Sesamum, Hemp, Paper Mulberry, Cotton, Indigo, Isatis indigotica, Urtica nivea.

### 7. *Region of the Scitamineæ (Indian, or Roxburgh's Region).*

*Mean temperature*, 60°-83° Fahr.

*Character.*—The tropical Orders make their appearance, or become more abundant: Palmæ, Cycadeæ, Scitamineæ, Aroideæ, Artocarpeæ, Urticeæ, Euphorbiaceæ, Lauraceæ, Convolvulaceæ, Bignoniaceæ, Apocyneæ, Rubiaceæ, Leguminosæ, Terebinthaceæ, Meliaceæ, Guttiferæ, Sapindaceæ, Byttneriaceæ, Malvaceæ.

The extra-tropical vanish, or only present themselves sparingly: Cariceæ, Coniferæ, Amentaceæ, Labiatæ, Boragineæ, Compositæ, Rosaceæ, Caryophylleæ, Cistaceæ, Cruciferæ, Ranunculaceæ.

*Genera.*—Uvaria, Grewia, Eriolæna, Garcinia, Buchanania, Crotolaria, Flemingia, Butea, Carpopogon, Jambosa, Gratiola, Tectona, Holmskioldia, Ficus, Phytocrene, Calamus.

The trees are never without leaves. The number of arborescent plants is greater than outside the tropics. Large and splendid flowers. Many climbing, parasitical, and epiphytic plants.

*Predominant arborescent plants.*—Dillenia ornata, D. scabrella, Uvaria, sp., Michelia Campaca, &c., Bombax insignis, &c., Sterculia, sp., Astrapæa Wallichii, Elæocarpus, sp., Calophyllum, sp., Garcinia, sp., Sapindus, sp., Swietenia febrifuga, Cissus, sp., Aquilaria malaccensis, Semecarpus Anacardium, Melanorrhœa usitata, Mimosa, sp., Acacia, sp., Amherstia nobilis, Pterocarpus santalinus, Cassia fistula, Jambosa, sp., Gardenia, sp., Nauclea, sp., Uncaria Gambir, Diospyros Ebenum, &c., Urceola elastica, Bignonia, sp., Avicennia tomentosa, Tectona grandis, T. Hamiltoniana, Laurus Cassia, L. Cinnamomum, L. malabathrica, Tetranthera, sp., Myristica, sp., Hernandia sonora, Ficus religiosa, F. indica, F. elastica, F. benjamina, and many others; Cycas revoluta, Borassus flabelliformis, Cocos nucifera, Elate sylvestris, Metroxylon Sagus, Calamus Rotang, C. rudentum, C. Draco, &c., Areca Catechu, Taliera bengalensis, Dracæna Draco, Pandanus odoratissimus, Flagellaria indica, Bambusa arundinacea.

*Cultivated plants.*—Rice, Millets, &c. (Panicum frumentaceum, Eleusine coracana, Sorghum, sp.), Sago (Cycas circinalis), Yams, Ground-nut (Arachis), Cocoa-nut, Tamarind, Mango, Mangosteen, Banana, Plantain, Rose-Apples (Eugenia, Jambosa), Guava, Oranges of various kinds, Shaddock, Water-Melon, Sugar, Coffee, Cloves, Peppers, Ginger, Cardamums, Turmeric, Cotton, Indigo, &c., Soja, Beans, Pulses (Dolichos, sp.).

### 8. *Region of Rhododendron-trees* (*Emodic, or Wallich's Region*).

*Altitudes*, 5,000–12,000 feet. *Mean temperature*, 66°–37° Fahr.

*Character.*—Tropical forms disappear or decrease:—Palmæ, Cycadeæ, Scitamineæ, Euphorbiaceæ, Solanaceæ, Convolvulaceæ, Apocynaceæ, Terebinthaceæ, Leguminosæ, Malvaceæ, Anonaceæ.

Extratropical, especially European, forms come to light, or become more abundant than in 7, such as Cariceæ, Amentaceæ, Coniferæ, Polygoneæ (Rumex, Polygonum, Rheum), Primulaceæ (Primula, Lysimachia), Labiatæ, Ericaceæ (Rhododendron, Andromeda), Cichoraceæ, Umbelliferæ, Rosaceæ (Potentilla, Rubus, Rosa, Pyrus, Mespilus, Prunus), Aceraceæ, Caryophyllaceæ (Stellaria, Cerastium, Arenaria), Cruciferæ, Ranunculaceæ (Aconitum, Ranunculus, Thalictrum). The Orchideæ and Ferns are very numerous. Other characteristic forms are the

*Genera.*—Allium, Paris, Plantago, Veronica, Rhinanthus, Pedicularis, Didymocarpeæ, Gentiana, Swertia, Campanula, Valeriana, Galium, Cornus, Viburnum.

*Most important trees and shrubs.*—Pinus Pindrow, P. Webbiana, P. excelsa, P. Khutrow, P. Gerardiana, Abies Smithiana, A. Browniana, Cedrus Deodara, Cupressus torulosa, Podocarpus latifolia, Juniperus squamata, J. excelsa, Quercus spicata and ten other sp., Corylus ferox, Betula utilis, B. nitida, B. alnoides, Alnus nepalensis, Salix disperma, S. cuspidata, S. japonica, Daphne cannabina, D. Gardneri, D. sericea, D. Bholua, Elæagnus arborea, E. conferta, E. umbellata, Hippophaë salicifolia, Fraxinus floribunda, Ligustrum nepalense, L. bracteolatum, Xylosteum ligustrinum, Caprifolium japonicum, C. macranthum, Cornus oblonga, C. capitata, Viburnum fœtidum &c., Andromeda formosa, A. ovalifolia, &c., Rhododendron arboreum, R. barbatum, R. Falconeri, and many other sp.; Hedera Hainla, &c., Ilex dipyrena, I. odorata, &c., Ribes Takare, Rosa microphylla, &c., Rubus rugosus, R. betulinus, &c., Spiræa canescens, &c., Neillia thyrsiflora, N. rubiflora, Pyrus Pashia, Mespilus affinis, M. Cuila,

&c., Prunus undulata, P. cerasoides, Rhus juglandifolium, R. fraxinifolium, &c., Rhamnus, sp., Celastrus, sp., Euonymus, sp., Acer acuminatum, A. oblongum, Dobinæa vulgaris, Magnolia, sp., Berberis asiatica, B. Wallichiana, B. Miccia.

*Note.*—The western portion of the Himalayas differs considerably from the eastern portion, from the predominance of Dicotyledonous forests and a damp climate in the former, with a rarity of Conifers until the limit of Abies Smithiana (10,000 feet) is attained, and an extension of the tropical plants to a greater altitude; while in the drier eastern portion the Conifers are diffused throughout, the forests less considerable, and the plants of temperate climates diffused lower down.

*Cultivated plants.*—The cereals and orchard fruits of Europe, mountain Rice, and a few tropical plants in the lower regions.

### 9. *Polynesian* (*or Reinwardt's*) *Region.*

*Mean temperature*, 66°–84° Fahr. *Altitude*, 0–5000 feet.

*Character.*—Resembling that of the Indian region. The principal distinction consists in the greater number of Orchideæ (especially parasitic species, which appear here in many peculiar forms), of Ferns, and species of Ficus. A slight approximation to the Australian forms: Melaleuca, Metrosideros, Proteaceæ (Heliophyllum). Among the other characteristic forms are the

*Genera.*—Licuala, Lodoicea, Rafflesia, Brugmansia, Stemonurus, Antiaris, Myristica, Nomaphila, Hydrophytum, Philagonia, Esenbeckia, Echinocarpus, Aromadendron.

*Predominant trees and shrubs.*—Primæval forests, composed especially of species of Ficus, Lauraceæ, Calameæ, and Bignoniaceæ, with Licuala speciosa, Lodoicea seychellarum, Broussonetia papyrifera, Artocarpus incisa, Antiaris toxicaria (Upas), Myristica, sp., Ardisia, sp., Tectona grandis, Strychnos Tieute, Diospyros, sp., Barringtonia speciosa, B. excelsa, Philagonia procera, Cereus, sp., Calophyllum Inophyllum, Elæocarpus, sp., Esenbeckia altissima, Echinocarpus Sigun.

*Cultivated plants.*—The same as in the Indian region, with Bread-fruit, Cassava, Inocarpus edulis, Nutmeg, Camphor, Papaw, Cotton (tree, &c.), Paper-mulberry, Hemp.

### 10. *Upper Javan* (*or Blume's*) *Region.*

*Altitude*, 5000–12,000 feet.

*Character.*—This region bears a certain resemblance to the Emodic region, and ought perhaps to be united with it. Extratropical forms replace the tropical. Oak-woods replace the forests of Ficus; and these are succeeded by forests of Podocarpus mingled with Ternstrœmiaceous trees, above which the shrubby Heaths (Thibaudia) and woody Gnaphalia occur at a comparatively low elevation (9000 feet), where the trees cease.

*Genera.*—Plantago, Lysimachia, Veronica, Gentiana, Swertia, Vaccinium, Gaultheria, Vireya, Thibaudia, Bellis, Galium, Saprosma.

*Characteristic trees and shrubs.*—Ternstrœmiaceæ (Cleyera), Gordonia, Schima, Eurya, Meliaceæ, arborescent Eupatorieæ, Lauraceæ, Ficus, Podocarpus amara, P. imbricata, P. latifolia, P. bracteata, Agathis loran-

thifolia, Quercus, 16 sp., Myrica javanica, Castanea javanica, C.
&c., Lithocarpus javensis, Engelhardtia spicata, E. rigida, Thiba
Bongosa, sp., Viburnum, sp., Sambucus javanica, Hæmospermu
reum, Mespilus, sp.

### 11. *Oceanic (or Chamisso's) Region.*

*Mean Temperature*, 73°–83° Fahr.

*Character.*—A sparing and not very peculiar flora. Greater
mation to the flora of Asia than to that of Africa; some affinit
Australian (Casuarina, Proteaceæ, Myoporum, Epacridēæ, M
Acaciæ aphyllæ).

*Genera.*—Schiedea, Antholoma, Aporetica, Crossostylis, Codia
nius, Kadua, Cyathostegia, Argophyllum, Melodinus, Ascarina.

*Predominant trees and shrubs.*—Dracæna terminalis, Tacca pin
Pandanus odoratissimus, Cocos nucifera, Corypha umbraculifera,
columnaris, Casuarina equisetifolia, C. nodiflora, Ficus, sp., Ar
incisa, Aleurites triloba, Embothrium strobilinum, Scævola Kœni
cinium cereum, Lobelia arborea, &c.; Coffea kaduana, C. M
Kadua Cookiana, &c., Rhizophora Mangle, R. gymnorhiza, Te
Catalpa, Barringtonia speciosa, Melaleuca virgata, &c., Osteomeles
lidifolia, Cassia Sophora, Mimosa Mangium, Adenanthera scandens,
burnea pinnata, Calophyllum Inophyllum, Clusia sessilis, C. ped
Sapindus Saponaria, Dodonæa spathulata, D. viscosa, Aporetica
A. ternata, Grewia Mallococca, Sterculia Balangas, S. fœtida, Comm
echinata, Tetracera Euryandra.

*Cultivated plants.*—Bread-fruit, Taro (Arum esculentum), A
gittifolium, A. microrhizon, Tacca pinnatifida, Convolvulus chry
Yam (Dioscorea alata), Cocoa-nut, Banana, Inocarpus edulis,
Balangas, Ficus aspera, F. Granatum, Shaddock, Hog-plum (
dulcis), Mimusops dissecta, Terminalia glabra, Cratæva religiosa,
malaccensis, Dracæna terminalis, Macropiper methysticum, Areca
Paper-mulberry.

### 12. *Region of Balsamic trees (Arabian or Forskål's Region*

*Character.*—Tropical; in greatest part, Indian forms.

*Characteristic genera.*—Stræmia, Mærua, Serræa, Oncoba, Cau
Geruma, Balsamodendron, Cadia, Orygia, Simbuleta. Some app
tion to the South-African flora (Stapelia, Hæmanthus).

*Predominant trees and shrubs.*—Pandanus odoratissimus, Ficus
morus, F. salicifolia, F. populifolia, F. Forskålii, F. palmata, F. se
Sur, F. Toka, Avicennia tomentosa, Cynanchum arboreum, Balsa
dron gileadense, B. Opobalsamum, B. Kataf, B. Kaful, Celastrus
C. parviflora, Grewia populifolia, Mærua uniflora, M. racemosa.

*Cultivated plants.*—Millets (species of Sorghum), six-rowed
Maize, Arum Colocasia, Date-palm, Plantain, Cocoa-nut, Tamari
Papaw, Peach, Apricot, Plum, Apple, Quince, Vine, Coffee, Sugar,
Radish, Spinach, Gourd, Dolichos, sp., Tree-cotton, Indigo.

*Note.*—This region extends to the plains of North-east India (S
and should probably include part of Persia, and also of the Aby
region.

### 13. *The Desert Region* (*Delile's Region*).

*Mean temperature*, 73°–86° Fahr.

*Character.*—A very poor flora. No characteristic Orders or genera, but the following species: Pennisetum dichotomum, Phœnix dactylifera, Cucifera thebaica, Euphorbia mauritanica, Ærua tomentosa, Acacia nilotica, A. arabica, A. gummifera, A. Senegal, Cassia obovata, C. Singueana, Alhagi maurorum, Mimosa Habbus, Zizyphus Palma Christi, Zygophyllum simplex, Z. album, Fagonia arabica, F. Oudneyi.

*Cultivation.*—Only in the Oases; here principally the Date-Palm. Doura (Sorghum vulgare), Wheat, Barley. South-European and certain Indian fruits.

### 14. *Region of Tropical Africa* (*Adanson's Region*).

[*The Interior little known.*]

*Mean temperature*, 73°–86° Fahr.

*Character.*—The flora is remarkable for the large number of peculiar generic types, each often containing but few species. Leguminosæ, Rubiaceæ, Cyperaceæ very prevalent. Comparatively few species of Palmæ, Filices, Scitamineæ, Piperaceæ, Passifloreæ.

*Genera.*—Adansonia, Dombeya, Melhania, Christiania, Pentadesma, Napoleona, Parkia, Thonningia.

*Predominant trees and shrubs.*—Anona senegalensis, &c., Cadaba farinosa, Cratæva Adansonii, Capparis edulis, Pentadesma butyracea, Bombax pentandrum, B. guineense, Adansonia digitata, Sterculia acuminata, Grewia carpinifolia, Acacia, sp., Cassia occidentalis, Pterocarpus esculentus, Parkia africana, Chrysobalanus Icaco, Conocarpus pubescens, Rhizophora, sp., Psychotria, sp., Bignonia tulipifera, Avicennia africana, Euphorbia (shrubby species), Ficus, sp., Elais guineensis, E. melanococca, Rhapis vinifera, Phœnix spinosa, Pandanus candelabrum.

*Cultivated plants.*—Maize, Rice, Millets (Sorghum vulgare, saccharatum, Panicum, sp.), Yam (Dioscorea alata, sativa), Cassava, Arum esculentum, Plantains, Mango, Papaw, Pine-apple, Oil-palm, Cashew-nut, Figs, Tamarind, Citrus, sp. (Oranges, Limes, Lemons, &c.), Coffee, Sugar, Ginger, Cardamoms, Grains of Paradise, &c., Beans of various kinds, and Dolichos pulses, Ground-nut (Arachis), edible Solana, Cotton, Tobacco.

### 15. *Region of Cacti and Piperaceæ* (*Jacquin's Region*).

*Mexico, Guiana, &c.*

*Altitude*, up to 5000 feet. *Mean temperature*, 68°–84° Fahr.

*Character.*—Bromeliaceæ, Piperaceæ, Passifloraceæ, Cactaceæ, Euphorbiaceæ, Convolvulaceæ, Apocynaceæ, Rubiaceæ. Tropical Orders less frequent here than in other places within the tropics: Filices, Scitamineæ, Orchidaceæ, Myrtaceæ, Leguminosæ, Terebinthaceæ, Aurantiaceæ, Tiliaceæ, Malvaceæ. Extratropical Orders appearing or becoming more abundant: Labiatæ, Ericaceæ, Campanulaceæ, Compositæ, Umbelliferæ, Crassulaceæ, Rosaceæ, Caryophyllaceæ, Cruciferæ, Ranunculaceæ.

*Characteristic genera.*—Phytelephas, Kunthia, Galactodendron, Podopterus, Salpianthus, Russellia, Lagascea, Gronovia, Inga, Thouinia, Lacepedia, Theobroma, Guazuma.

*Predominant trees and shrubs.*—Cyathea spinosa, C. villosa, Meniscium arborescens, Agave americana, Yucca acaulis, Cocos nucifera, C. butyracea, Mauritia flexuosa, Martinezia caryotifolia, Oreodoxa montana, Kunthia montana, Chamærops Morini, Corypha Miraguama, C. Pumos, C. tectorum, &c., Liquidambar styraciflua, Cecropia peltata, Galactodendron utile, Rhopala ovata, Avicennia tomentosa, Ehretia ternifolia, Cordia dentata, Cereus, sp., Melocactus, sp., Opuntia, sp., Pereskia, sp., Mammillaria, sp., Lecythis elliptica, &c., Bertholletia excelsa, arborescent Melastomæ, Bauhinia splendens, B. suaveolens, &c., Hæmatoxylon campechianum, Cæsalpinia cassioides, &c., Acacia cornigera, A. fœtida, &c., Hymenæa Courbaril, &c., Inga Humboldtiana, I. insignis, &c., Mimosa, sp., Swietenia Mahogani, Bonplandia trifoliata.

*Cultivated plants.*—Maize, Doura, Cassava, Yam, Batatas, Plantain, Mango, Custard-apples, Guavas, Cocoa-nut, Papaw, Peach, Pine-apple, Cashew-nut, Tamarind, species of Citrus, Granadilla, Vine, Cactus-fig, Rose-apple, Cocoa, Vanilla, Coffee, Sugar, Tomatos, Capsicums, Pigeon-peas (Cajanus), Ground-nut, Cochineal-cactus, Tobacco, Cotton.

### 16. *Region of the Mexican Highlands* (*Bonpland's Region*).

*Altitude*, above 5000 feet. *Mean temperature*, 67°–79° Fahr.

*Character.*—Tropical forms vanishing or decreasing: Tree-ferns, Palmæ, Piperaceæ, Euphorbiaceæ, Melastomaceæ, Passifloraceæ. Extratropical forms make their appearance or become more abundant: Amentaceæ (Salix, Quercus), Coniferæ (Pinus, Cupressus), Labiatæ (Salvia, Stachys, Marrubium), Pedicularis, Anchusa, Myosotis, Polemonium, Ericaceæ (Vaccinium, Arbutus, Arctostaphylos), Compositæ (greatly increasing), Valeriana, Galium, Cornus, Caprifolium, Umbelliferæ, Rosaceæ (Amygdalus, Mespilus, Rosa, Potentilla), Caryophylleæ (Arenaria), Cruciferæ (Draba), Ranunculaceæ (Anemone, Ranunculus).

*Characteristic genera.*—Mirabilis, Maurandya, Leucophyllum, Holtzia, Dahlia, Zinnia, Schkuhria, Ximenesia, Lopezia, Vauquelinia, Choisya, Cheirostemon.

*Predominant trees and shrubs.*—Pinus occidentalis, Abies hirtella, Cupressus thurifera, C. sabinoides, Taxodium distichum, Quercus (16 sp.), Salix Bonplandiana, S. paradoxa, &c., Arbutus mollis, A. petiolaris, Arctostaphylos polifolia, A. pungens, &c., Vaccinium geminiflorum, V. stamineum, V. confertum, Rosa Montezumæ, Mespilus pubescens, Amygdalus microphylla, Cheirostemon platanoides.

*Cultivated plants.*—Maize, European cereals and fruits.

*Note.*—In the uppermost regions of the mountains the flora acquires an alpine aspect. Here occur Cyperus toluccensis, Chelone gentianoides, Cnicus nivalis, Ageratum arbutifolium, Senecio (many procumbent species), Potentilla ranunculoides, Lupinus elegans, L. montana, Arenaria bryoides.

### 17. *Region of Cinchonas* (*Andes, or Humboldt's Region*).

*Altitude*, 5000-9000 feet. *Mean temperature*, 59°–68° Fahr.

*Character.*—Extratropical forms make their appearance, or become more frequent. Graminaceæ, Amentaceæ (Quercus, Salix), Labiatæ (Salvia, Stachys, Scutellaria), Anchusa, Myosotis, Swertia, Ericeæ, Compositæ (very numerous), Caprifoliaceæ (Viburnum, Sambucus), Umbelliferæ (Ferula, Ligusticum), Rosaceæ, Cruciferæ, Ranunculaceæ. On the other hand, certain tropical forms vanish or become rarer, but a few particular species of Palmæ, Piperaceæ, Cactaceæ, Passiflora, and Melastomaceæ ascend to a considerable altitude.

*Genera.*—Lilæa, Cervantesia, Oreocallis, Lachnostoma, Gaylussaccia, Stevia, Flaveria, Tagetes, Espeletia, Cinchona, Guilleminia, Loasa, Kageneckia, Negretia, Amicia, Perottetia, Dulongea, Laplacea, Freziera, Abatia, Monnina.

*Predominant trees and shrubs.*—Oreodoxa frigida, Ceroxylon andicola, Podocarpus taxifolia, Salix Humboldtiana, Quercus Humboldtiana, Q. almaguerensis, Q. tolimensis, Ficus velutina, Rhopala cordifolia, Oreocallis grandiflora, Persea lævigata, P. Mutisii, P. sericea, Ocotea mollis, O. sericea, Vaccinium caracasanum, Andromeda bracamorensis, Befaria glauca, B. ledifolia, Cinchona Condaminea, C. cordifolia, C. oblongifolia, C. lancifolia, &c., Weinmannia elliptica, W. Balbisiana, &c., Osteomeles glabrata, Rubus floribundus, Ilex bumeloides, I. myricoides, Clusia elliptica.

*Cultivated plants.*—The tropical cultivated plants mentioned under 15 almost entirely disappear; Maize and Coffee, however, are cultivated in this region; after these come the European cereals and fruits, Potatoes, and Chenopodium Quinoa.

### 18. *Region of Escalloniæ and Calceolariæ* (*Ruiz and Pavon's Region*).

*Altitude*, 9000–18,000 feet. *Mean temperature*, 59°–34° Fahr.

*Character.*—The tropical forms have disappeared almost entirely, but the following genera still occur:—Tillandsia, Oncidium, Peperomia, Rhexia, Passiflora. The forms which characterize the colder temperate and the polar zones become more common: Lichenales, Musci, Carex, Luzula, Alnus, Rumex, Plantago, Gentiana, Swertia, Vaccinium, Campanula, Cacalia, Senecio, Umbelliferæ, Valeriana, Saxifraga, Ribes, Rubus, Alchemilla, Caryophyllaceæ (Sagina, Arenaria, Cerastium, Stellaria), Cruciferæ (Draba, Arabis).

*Predominant Orders.*—Compositæ, Graminaceæ, Ericaceæ. No large trees.

*Characteristic genera.*—Desyeuxia, Tigridia, Gardoquia, Calceolaria, Thibaudia, Lysipoma, Barnadesia, Homanthis, Chuquiruga, Culcitium, Wernera, Dumerillia, Escallonia, Pectophytum, Klaprothia, Polylepis.

*Predominant shrubs.*—Alnus ferruginea, A. acuminata, Vaccinium acuminatum, V. empetrifolium, V. floribundum, &c., Thibaudia rupestris, T. floribunda, T. longifolia, T. strobilifera, Befaria grandiflora, B. coarctata, Ribes frigidum, Escallonia myrtilloides, E. tortuosa, E. berberidifolia, Ilex scopulorum, Drymis granatensis.

### 19. *West-Indian* (*or Swartz's*) *Region.*

*Mean temperature*, 59°–79° Fahr.

*Character.*—The flora of this group of islands approaches that of the adjacent continent, but is distinguished especially (like the Polynesian from the Indian flora) by the great quantity of Filices and Orchidaceæ. In addition to these Orders, we find among the characteristic forms the following:—

*Genera.*—Thrinax, Epistylium, Alchornea, Tanaëcium, Tetranthus, Catesbæa, Belonia, Portlandia, Picramnia, Legnotis, Lithophila, Valentinia, Hypelate.

The following are deserving of mention among the predominant trees and shrubs:—Cocos nucifera, Pinus occidentalis, Laurus, sp., Melastoma, sp., Myrtus, sp., Sterculia, sp., Uvaria, sp.

*Cultivated plants* the same as in 15.

### 20. *Region of Palms and Melastomæ* (*Brazilian or Martius's Region*).

*Mean temperature*, 59°-84° Fahr.

*Character.*—Probably that portion of the globe in which the Vegetable Kingdom presents the greatest profusion and variety. Abundance of genera and species, magnitude of individuals, impenetrable (primæval) forests, numerous climbing and parasitical plants. Among the characteristic although not peculiar Orders may be named Palmæ, Hæmodoraceæ, Gesneraceæ, Melastomaceæ, and Sapindaceæ; the Vochysiaceæ are peculiar. The peculiar genera are too numerous to be all mentioned here; among those richest in species are the

*Genera.*—Vellosia, Barbacenia, Manihot, Franciscea, Ditassa, Lycnophora, Diplusodon, Kielmeyera, Sauvagesia, Lavradia.

*Characteristic genera and species, according to the different modes of occurrence.*—In the primæval forests: Palms of various genera, Thoa, Ficus, Cecropia, Anda, Rhopala, Myristica, Bignonia, Theophrasta, Stifftia, Oxyanthus, Coutarea, Psychotria, Bertiera, Feuillea, Carica, Myrtus, Gustavia, Lecythis, Bertholletia, Melastoma, Hymenæa, Dimorpha, Trattinickia, Pilocarpus, Trichilia, Cedrela, Cupania, Banisteria, Hippocratea, Caryocar, Marcgravia, Clusia, Calophyllum, Sloanea, Göthea, Lebretonia, Abroma, Carolinea, Bixa, Uvaria.

In the Catingas (or open woods, where the trees lose their leaves in the dry season): Jatropha, sp., Acacia, sp., Mimosa, sp., Cæsalpinia pubescens, &c., Spondias tuberosa, Thryallis brasiliensis, Chorisia ventricosa, Bombax, sp., Eriodendron, sp., Pourretia ventricosa, Capparis lineata, &c., Anona obtusifolia, &c.

In the Campos (open treeless plains): Paniceæ, Amaryllis, Alstrœmeria, Vellosia, Barbacenia, Burmannia, Stelis, Cnemidostachys, Rhopala, Laurus, Ocotea, Gomphrena, Lantana, Echites, Hancornia speciosa, Gesnera, Lycnophora, Baccharis, Vernonia, Mikania, Stevia, Melastoma, Rhexia, Terminalia fagifolia, Gaudichaudia, Sauvagesia, Lavradia, Plectanthera.

On the sea-coasts: Cocos schizophylla, Diplothemium maritimum, Eriocaulon, sp., Xyris, sp., Avicennia tomentosa, Rhizophora Mangle, Conocarpus erectus, Laguncularia racemosa, Bucida Buceras.

*Cultivated plants*, about as in 15.

### 21. *Region of shrubby Compositæ (Extratropical S.-American, or St.-Hilaire's Region).*

*Mean temperature*, 59°–74° Fahr.

*Character.*—The tropical forms decrease or vanish; extratropical, especially European, forms take their place: Ranunculaceæ, Cruciferæ, Helianthemum, Caryophyllaceæ, Lathyrus, Galium, Teucrium, Plantago, Carex; a few South-African forms, Polygala, Oxalis, Gnaphalium. This region has more than half its genera in common with Europe. Numerous Compositæ; many among these shrubby.

*Genera.*—Larrea, Hortia, Diposis, Boopis, Acicarpha, Cortesia, Petunia, Jaborosa, Tricycla, Caperonia, Bipennula. In great part consisting of open flat plains (Pampas), over which Grasses and Thistles prevail.

*Cultivated plants.*—Mostly the European: Wheat, Vine. The Peach is very widely spread.

### 22. *The Antarctic Region (D'Urville's Region).*

*Mean temperature*, 41°–48° Fahr.

*Character.*—Great resemblance to the North-European flora (Region 2). The tropical forms have entirely vanished.

*Predominant Orders.*—Compositæ, Graminaceæ, Cariceæ, Musci, Lichenes. The following are also common: Ranunculaceæ, Cruciferæ, Caryophyllaceæ, Rosaceæ, Umbelliferæ. Two-thirds of the genera in common with Europe. A slight approximation to South Africa (Gladiolus, Witsena, Galaxia, Crassula) and to Australia (Embothrium, Ourisia, Stylidiæ, Mniarum).

*Characteristic genera.*—Gaimardia, Astelia, Callixene, Philesia, Drapetes, Bæa, Calceolaria, Pernettya, Oligosporus, Nassavia, Bolax, Azorella, Donatia, Acæna, Hamadryas.

*Predominant trees and shrubs.*—Fagus antarctica, Salix magellanica, Embothrium coccineum, Pernettya empetrifolia, P. mucronata, Andromeda myrsinites, Baccharis tridentata, Chiliotrichum amelloides, Ribes magellanicum, Escallonia serrata, Fuchsia coccinea, Myrtus nummularia, Berberis ilicifolia, B. inermis, B. microphylla, B. empetrifolia, Drimys Winteri. No cultivation.

### 23. *Region of Stapeliæ and Mesembryanthema (S. African, or Thunberg's Region).*

*Mean temperature*, 54°–73° Fahr.

*Character.*—A flora very rich in forms, but not luxuriant; no large dense forests, or abundance of climbing plants, &c.; many succulent plants.

*Characteristic Orders.*—Restiaceæ, Iridaceæ, Proteaceæ, Ericaceæ, Ficoideæ, Bruniaceæ, Diosmeæ, Geraniaceæ, Oxalideæ, Polygalaceæ.

*Genera.*—Restio, Ixia, Gladiolus, Moræa, Watsonia, Hæmanthus, Strumaria, Agapanthus, Eucomis, Massonia, Strelitzia, Passerina, Gnidia, Protea, Leucadendron, Leucospermum, Serruraria (and many other Proteaceæ), Stilbe, Selago, Stapelia, Erica, Gnaphalium, Helichrysum, Stobæa, Pteronia, Osteospermum, Tarchonanthus, Relhania, Gorteria, Arctotis, Othonna, Stœbe, Œdera, Anthospermum, Mesembryanthemum, Vahl Liparia, Borbonia, Lebeckia, Raffnia, Aspalathus, Stavia, Brunia, Phylic Diosma, Pelargonium, Oxalis, Sparmannia, Muraltia, Polygala, Pena Welwitschia.

*Predominant forms.*—On the sandy districts of the coasts: Stapeli Iridaceæ, Mesembryanthemum, Restio, Diosma. On the mountai Proteaceæ, Erica, Crassula, &c. On the dry plateaux: Acacia capens A. giraffæ, A. detinens, A. viridamis, Euphorbia mauritanica, E. tena Poa spinosa, Mesembryanthemum, sp., Aloe, Iridaceæ, Erica, Diosme Restio.

*Other remarkable species.*—Hæmanthus coccineus, Amaryllis toxicar Testudinaria montana, T. elephantipes, Podocarpus elongatus, Sal gariepina, Protea mellifera, P. grandiflora, Leucadendron argenteu Laurus bullata, Lycium tetrandrum, Olea similis, Rhizogum trichotomu Tarchonanthus camphoratus, Stœbe rhinocerotis, Crassula coccinea, Po tulacaria afra, Mesembryanthemum edule, M. turbiniforme, Metrosider angustifolia, Acacia elephantina, Zizyphus bubalina, Calodendron capens Welwitschia mirabilis, Succulent vines (Vitis), &c.

*Cultivated plants.*—The European cereals, fruits, and esculent veg tables; also Sorghum caffrorum, Batatas, Plantains, Tamarind, Guav Shaddock.

### 24. *Region of the Eucalypti and Epacrides* (*Australian, or R. Brown's Region*).

*Mean temperature*, 53°–73° Fahr.

*Character.*—One of the richest and most peculiar floras, but withou any considerable profusion of vegetation.

*The characteristic orders and genera are*—Xerotes, Xanthorrhœ Pterostyles, Casuarinæ, Leptomeria, Pimelea, Proteaceæ (Banksia, Hake Persoonia, Grevillea, Petrophila, Isopogon, Dryandra), Myoporineæ, Westringia, Logania, Mitrasacme, Epacridaceæ (Epacris, Leucopogon, Styphelia), Stackhousieæ, Scævoleæ, Goodenovieæ, Stylideæ, Eucalyptu Melaleuca, Leptospermum, Acaciæ aphyllæ, Platylobium, Bossiæa, Diosmeæ (Boronia, Zieria), Pittosporeæ, Tremandreæ, Pleurandra, Hibberti

*Predominant trees and shrubs.*—Three-fourths of the forests are composed of species of Eucalyptus, the number of which amount to more tha a hundred. Next to these come Proteaceæ, Epacrideæ, Diosmeæ, Casuarinæ, and Acaciæ aphyllæ, forming woods and "bush." Also Coniferæ Araucaria excelsa, A. Bidwilli, A. Cunninghamii, Cookii, Dacrydiun Franklinii, Podocarpus spinulosa.

*Cultivated plants.*—In the European colonies the cereals, fruits, and vegetables of Europe.

### 25. *New-Zealand Region* (*Forster's Region*).

*Temperate climate.*

*Character.*—Tropical forms vanish, or appear but sparingly. Half the genera European. Approximation to Australia (Pimelea, Myoporum, Epacris, Styphelia, Cassinia, Melaleuca); to South Africa (Gnaphalium, Xeranthemum, Tetragonia, Mesembryanthemum, Oxalis); to the Antarctic region (Mniarum, Fuchsia, Acæna, Drimys). Very many Ferns.

*Genera.*—Phormium, Pennantia, Knightia, Forstera, Griselinia, Melicope, Dicera, Plagianthus, Melictus.

*Characteristic species.*—Cyathea medullaris, Gleichenia furcata, Dracæna indivisa, D. australis, Phormium tenax, Areca sapida, Dacrydium taxifolium, Dammara australis, Podocarpus Totarra, Knightia excelsa, Avicennia resinifera, Andromeda rupestris, Epacris juniperina, &c., Weinmannia racemosa, Tetragonia expansa, Fuchsia excorticata, Melaleuca, sp., Dicera dentata, D. serrata.

*Cultivated plants.*—Arum esculentum, Convolvulus chrysorhizus, Phormium tenax (New-Zealand flax), Paper-mulberry. In the European colonies the cereals, fruits, and esculents of Central Europe.

## Sect. 4. STATISTICS OF VEGETATION.

Various authors have made computations from existing data, with a view to ascertain the total number of existing species of Phanerogamia; but as the opinions of authors as to what limits a species are so extremely varied, it seems useless to occupy space with such speculative matter. The computations range from 100,000 to 300,000 species and upwards. It is somewhat more easy to lay down some general statistical facts regarding the distribution, and particularly in reference to the relative proportions of the more important Classes and Orders, in different regions of the globe.

947. Materials are insufficient to enable us to calculate the relative distribution of Cryptogamia and Phanerogamia in different regions. The former appear to bear a higher proportion to the latter as we recede from the equator to the poles; but this may depend upon our better acquaintance with the Cryptogamic Floras of the northern temperate regions than with the Cryptogamia of the warmer climates.

948. As regards the relative abundance of Monocotyledons and Dicotyledons in different latitudes, it is generally agreed that the proportion of Monocotyledons to Dicotyledons increases from the equator towards the poles,—a retrogression of the proportional number taking place, however, in the icy regions of the poles and on alpine summits. As a rule also, closely connected with the above statements, Monocotyledons are more predominant in proportion to the greater moisture of a climate.

949. Probably no Orders, except the Leguminosæ and the Compositæ, contain a number of species amounting to 5 per cent. of the total number of Phanerogamic species. Thus the existence of species of one Order in any region exceeding in number 5 per cent. of all the species found there, indicates a predominance of that Order. If such predominance occur only in one region, the Order becomes

*characteristic* of that region; if such predominance of the same Order occur in many regions, it indicates *wide diffusion* of that Order.

In a very long list of Floras, from all parts of the globe, compared by Alph. De Candolle, it was found that only 35 Orders of Phanerogamia formed more than 5 per cent. in any one or several regions.

The Orders which presented in one or but a few floras from 10 to 19 per cent. of the Phanerogamic species were:—

| | |
|---|---|
| Caryophyllaceæ .. | Spitzbergen (14½ per cent.). |
| Cruciferæ ...... | Spitzbergen (19), and Melville Island (13½). |
| Leguminosæ .... | Almost all intertropical and subtropical regions. |
| Rubiaceæ ...... | Sierra Leone (10). |
| Proteaceæ ...... | Australia (11½). |
| Melastomaceæ .. | West coast of tropical America (11¼), Brazil (?). |
| Saxifragaceæ .... | Spitzbergen (14½), Melville Island (15). |
| Solanaceæ ...... | Ascension (13) (naturalized). |
| Myrtaceæ ...... | Brazil (?). |
| Cyperaceæ ...... | Lapland (13), Iceland (11), Brocken (12). |
| Orchidaceæ...... | New Guinea (16½), Java (10), Mauritius (11½), S. Mexico (10). |

Of Orders ordinarily exceeding 10 per cent. of a flora,—

Graminaceæ constituted 18 per cent. in Spitzbergen; 21 in Melville Island; 27 in Kerguelen's Land. Compositæ, 18½ per cent. in California and Mexico; 19 in the Malouines; 21 in Chili; 22 at Quito; 25 in the S. of Buenos Ayres; 27 in Juan Fernandez.

Orders with more than 30 per cent. occurred in exceptional localities, viz. Compositæ (33⅓) in the elevated parts of Chili, and Cyperaceæ (33⅓) at Tristan d'Acunha.

950. Certain Orders predominate in particular latitudes, without being in their nature characteristic of those latitudes.

Thus, while in some regions of the tropical zone the Palms, Zingiberaceæ, Marantaceæ, Melastomaceæ, Malpighiaceæ, &c. are really characteristic, the predominant species of the tropical floras are not members of such Orders as Lauraceæ, Menispermaceæ, Anonaceæ, Bombaceæ, which have their maximum in hot climates, but belong to the Leguminosæ, Graminaceæ, and Compositæ, which exceed 10 per cent. generally in the tropics: the Orchidaceæ and Cyperaceæ follow next, then Euphorbiaceæ, Urticaceæ, Melastomaceæ, and Scrophulariaceæ; of which, Melastomaceæ alone belong exclusively to hot regions.

Other Orders occurring in many tropical floras, but forming less than 5 per cent. of the species, are:—

Convolvulaceæ, Malvaceæ, Piperaceæ, Zingiberaceæ, and Marantaceæ, Solanaceæ, and less commonly Acanthaceæ, Amentaceæ, Apocynaceæ, Bignoniaceæ, Boraginaceæ, Capparidaceæ, Cucurbitaceæ, Gentianaceæ, Labiatæ, Lauraceæ, Loranthaceæ, Malpighiaceæ, Myrtaceæ, Umbelliferæ, Palmaceæ, Passifloraceæ, Rosaceæ, Rutaceæ, Anacardiaceæ, and Verbenaceæ.

The Ferns are likewise exceedingly predominant in species in the islands of the tropics (16, 21, 26 per cent.).

In northern temperate latitudes (from the tropic to 60° N. lat.), again, Compositæ, Graminaceæ, Cyperaceæ, and Leguminosæ predominate in species; the Cyperaceæ increasing northward, the Leguminosæ rapidly decreasing (Granada 8 per cent., Yorkshire 4½ per cent.). Next follow Cruciferæ, Umbelliferæ, and Caryophyllaceæ; then Labiatæ, Rosaceæ, and Scrophulariaceæ. No other Orders exceed 5 per cent. of the species, and only attain this in exceptional localities.

In the northern zone beyond 60° N. lat., the species predominating northwards are Graminaceæ, Cruciferæ, Saxifragaceæ, Caryophyllaceæ, Ranunculaceæ, Rosaceæ, Cyperaceæ (5–7 per cent.). Compositæ form 7 per cent. in Melville Island, but only 4–5 per cent. in Spitzbergen. Amentiferæ (Betulaceæ, Salicaceæ, &c.) and Juncaceæ barely reach 5 per cent.; Polygonaceæ, Ericaceæ, and Scrophulariaceæ approach this number, but are mostly below it.

In the south temperate zone we find two classes of regions, one dry, the other with a damp climate. The former comprehends the Cape of Good Hope, Australia, Chili, and La Plata. Compositæ predominate at the Cape and in America, but in Australia fall to 7 per cent. Leguminosæ, on the contrary, make but 7 to 12 per cent. in America and at the Cape, but 14 per cent. in Australia. The Grasses are not more than 3 to 6 per cent. anywhere, and the Cyperaceæ still fewer.

The Cape and Australia have, however, certain especially abundant Orders; thus Proteaceæ form 2 to 6 per cent. at the Cape, 8–12 per cent. in Australia; Myrtaceæ 9 per cent., and Epacridaceæ 4–5 per cent. in Australia; Iridaceæ 4–6 per cent., Liliaceæ 4–5 per cent., and Ericaceæ 2–6 per cent. at the Cape; Stylidiaceæ and Goodeniaceæ are especially Australian.

In the moist regions, comprising parts of the African coast, Tasmania, New Zealand, Island of Chiloe, &c., the Grasses and Compositæ increase in departing from the tropics; Cyperaceæ rise to 4–8 per cent.; Orchidaceæ, 4½–8½ per cent.; and Ferns are very numerous in the islands. Restiaceæ increase in Tasmania, but Proteaceæ, Leguminosæ, with Stylidiaceæ, Goodeniaceæ, &c. decrease. The proportions in the southern extremity of America approach those of the temperate and moist regions of the northern hemisphere.

As a general statement, it may be said that of the three most frequently predominating Orders, Leguminosæ are diminished in proportion to temperature, the Compositæ are lessened by combined cold and humidity, and the Graminaceæ are least predominant where the climate is dry.

## CHAPTER III.

## BOTANICAL GEOLOGY.

### **Sect. 1.** NATURE AND IMPORTANCE OF FOSSIL PLANTS.

951. Remains and traces of plants are met with in most of the stratified rocks which have been produced by successive geological changes of the earth's surface. These remains afford an indication, more or less perfect in different cases, of the nature of the vegetation which has existed in earlier periods of the world's history. Vegetable remains found imbedded in geological formations are called *fossil plants*; and the condition in which these fossils occur are exceedingly varied, both as to the nature of the substance preserving the vegetable forms, and the degree of perfection of the forms preserved.

The principal kinds of fossils may be classed as follows:—1. *Petrified plants*, in which the structures of plants have been more or less completely impregnated with mineral matter, hardening them into a stony mass. They present various modifications, in which more or less of the organic matter remains, completely impregnated with mineral substances, or where the mineralization is so complete that the organic substance has totally disappeared. The mineral substance of such fossils is different in different cases. Silicified remains are the most common; fossils impregnated with carbonate or sulphate of lime abound in other strata, while fossils of dense or earthy ironstone, argillaceous ironstone, and, lastly, iron-pyrites are frequent in particular rocks; impregnations with rock-salt, oxide of copper, alumina, &c. are rarer.

2. *Coal*, where the vegetable substance is more or less completely converted into a solid, black, combustible carbonaceous substance, of stone-like aspect. This occurs in almost every possible modification, in masses or in the form of isolated plants or organs of plants, from the solid stony *anthracite* to the *brown coal* or *lignite*, which preserves the organic texture and is recognizable at first sight as vegetable matter. Coal-beds are formed through the accumulation of vast masses of vegetation, and their conversion through pressure and chemical changes into solid masses; but leaves, stems, or parts of stems, such as layers of bark, fruits, &c., converted into coal, are found isolated in strata of various composition. With these last are intimately connected the numerous fossils which are true petrifactions, but have the organic matter preserved in the mineral substance in the condition of coal, giving a coal-like aspect to the fossil.

3. *Impressions* or *natural casts* of plants or organs of plants, which have been formed by the vegetable objects being incrusted by, or imbedded in mineral substance and decaying subsequently to the solidification of the enclosing substance; the cavity left by the decayed vegetable may be filled up by the same or a different mineral substance; and casts of the internal parts of stems &c. are met with, from the penetration of the mineral matter into cavities formed by the quicker decay of succulent structures, such as pith.

4. *Objects contained in amber*, the fossil resin of a Pine, which has accidentally enclosed various vegetable and animal bodies which it flowed over while liquid. The objects are sometimes thoroughly impregnated with amber, like microscopic objects enclosed in Canada balsam, these having been enclosed in a dead or dry condition; in other cases, where fresh organs have been enclosed, hollow casts only are found, the enclosed matter having been more or less decomposed.

952. The study of vegetable fossils is far less satisfactory than that of animal remains, since, in the great majority of cases, the structures most distinctive of the subordinate groups of plants are formed of very perishable matter. Genera, and even species, of animals may be recognized by bones and shells, which are of a very persistent nature, and are found abundantly in stratified rocks. The preservation of fossils can only have occurred through the agency of water, impregnated with mineralizing matter, or loaded with mud which enclosed the remains: the vegetable bodies which can resist the long-continued action of water are few; and these mostly afford only characters of large sections of the vegetable kingdom, without furnishing generic, far less specific distinctions. Added to the fragmentary character of the fossils known, those kinds hitherto found possibly only represent partially prevailing forms of vegetation.

953. Attempts, however, have been made, by combining the conclusions of stratigraphical geology and animal palæontology with those of vegetable palæontology, to form conceptions of the character of the vegetation of succeeding geological periods. The ideas obtained in this way, however, are very superficial and exceedingly speculative. Still there is much that is promising in the investigations; and the general tendency of all the facts hitherto collected is to indicate that there has been a gradually increasing complexity of organization in the plants successively created, that the plants of the earliest epochs belong to the lower Classes, and that the higher Phanerogamia appeared only in the later formations—in the last of these probably in smaller proportion than in existing vegetation. In the earliest formations (Cambrian, Silurian, &c.) the few vegetable remains are those of Algæ, Fucoids, &c. In the Devonian and Carboniferous periods vascular Cryptogams, Ferns, Lycopods, Equiseta prevailed. In the Triassic and Oolitic periods Gymnospermous plants form a marked feature, also Conifers, Cycads, &c., with Tree-ferns and traces of Monocotyledonous plants. With the Cretaceous period appear Angiospermous plants, beginning with a preponderance of Incompletæ, and passing through Dialypetalæ to the more recent formations, where Gamopetalous plants prevail. But in all cases, though there is evidence of progress, there is an overlapping of the characteristics of one period by those of another.

954. One important point, however, must not be overlooked in inquiries relating to this subject; that is, the probability of the coexistence of diversified *local floras*, as at the present day, the remains of which might, from purely systematic considerations, be regarded as of different antiquity.

In illustration of this, it may be observed that the remains found in the European formations belonging to the epoch immediately preceding the present, offer a general resemblance to the prevailing forms of existing North-American vegetation.

## Sect. 2. FOSSIL PLANTS CHARACTERIZING PARTICULAR GEOLOGICAL FORMATIONS.

### 1. *Flora of the Palæozoic Strata.*

#### A. Lower and Middle Palæozoic, or Transition Period.

955. Comparatively few plants are known in these strata, and a considerable amount of uncertainty exists in reference to the determination of the fossils. What remnants remain in the Cambrian, Silurian, and Lower Devonian series are apparently those of marine Algæ. In the more recent deposits of this age, Ferns, Calamites, and Conifers are found.

#### B. Upper Palæozoic, or Carboniferous System.

956. The known floras of this system, remarkable for the presence of the great coal-beds of Europe, afford a very large number of species, in which there is a continued great predominance of the Leafy Cryptogamia (Ferns &c.).

The principal characteristics revealed here are the absence of Dicotyledons, the paucity of Monocotyledons, the predominance of the Ferns and allied Classes, and of certain plants of organization not met with in existing vegetation, referred by some authors to the Class of Gymnosperms, by others, and probably more correctly, to the vicinity of Lycopodiaceæ &c. Conifers and Cycads begin to appear, with Stigmarias, Sigillarias, *Lepidodendron*, &c. The general character of this flora is very monotonous, and alike in character from the poles to the equator.

This flora disappears almost entirely in the next System.

#### C. Permian System.

957. The fossils of these strata afford only fragmentary representatives of the Carboniferous flora, most of the characteristic genera

having disappeared. The Orders are much the same, but less numerously represented by species. Silicified coniferous wood, Ferns, and Algæ are found, and also evidence of the existence of Palms.

## 2. *Flora of the Mesozoic, or Secondary Strata.*

### A. Triassic, or New Red System.

958. In the "Variegated Sandstone" strata of this formation, comparatively few species have yet been observed. The Carboniferous species have disappeared; Ferns still predominate, and exhibit peculiar forms; Conifers (*Voitzia*, *Haidingera*) are abundant; Cycadeæ rare, and a few doubtful Monocotyledons (*Yuccites*, *Palæoxyris*) occur. In the "Keuper" Sandstones, with a general analogy in the proportion of Orders, except that Coniferæ are rare and Cycadaceæ abundant, the genera of Ferns and allied Orders are mostly distinct from those of the Vosgesian, or "Variegated" Sandstones.

### B. Liassic System.

959. The essential characters of this epoch are the great predominance of Cycadeæ, which here appear in several new genera, and the existence of Ferns with more highly organized foliage than that of the genera of older formations. Algæ, Fungi, Lichens, Lycopods, and Conifers also existed at this period.

### C. Oolitic System.

960. The nature of the strata referable here is very diverse; the general character of the fossil vegetation consists in abundance of Ferns proper, and of Cycadeæ, especially of those genera (*Zamites* and *Otozamites*) approaching nearest to existing forms, and the greater frequency of the Coniferæ, *Brachyphyllum* and *Thuytes*, than in the Lias. Algæ, Marsileas, Lycopods are also found. There are a large number of known species.

### D. Wealden System.

961. This formation, remarkable as a freshwater product, has afforded comparatively few species of plants, mostly congeneric, although specifically distinct from those of the Lias; but the proportion of the Cycadaceæ to the Ferns is smaller. *Equisetum* and *Chara* are represented.

### E. Cretaceous System.

962. In this formation we are at once struck with the diminution of Ferns, Equisetaceæ, and allied forms, the reduction of the

species of Gymnosperms, and the appearance of Angiospermous Phanerogamia, chiefly dicotyledonous (*Betula*, *Myrica*, *Salix*, &c.), though traces of Palms and Grasses have been met with. The Cycadaceæ are still numerous; but they and the Coniferæ do not more than equal the Dicotyledons. The genus *Credneria*, supposed to belong to the last class, is very characteristic of the Chalk formation. The Ferns and Equisetaceæ almost disappear.

### 3. *Floras of the Tertiary System.*

963. The floras of this system form a more or less connected whole, which is continued in the later strata into existing vegetation. They are especially distinguished from those of older epochs by the abundance of Angiospermous Phanerogamia, Dicotyledons, and Monocotyledons—above all, Palmaceæ. But a sort of transition takes place from the Cretaceous period to the Eocene. In this system, however, the proportion of Gymnosperms rapidly decreases, and the Cycadaceæ disappear from Europe, while the Conifers approach the character of the existing genera of temperate regions.

#### A. Eocene Flora.

964. The distinctive characteristics, as compared with other epochs, are the presence, though rare, of Palmaceæ, the comparative abundance of Algæ and marine Monocotyledons (*Caulinites*, *Zosterites*, &c.), and the existence in Europe of numerous now exotic forms, especially represented by the fossil fruits of the Isle of Sheppey, the Barton Bed in the Isle of Wight, &c. Though less rich than the Miocene, these formations include a large number of species of an Australian or Indo-Asiatic type. Leguminosæ of the suborder Cæsalpinieæ occur.

#### B. Miocene Flora.

965. A very rich flora. No less than 900 species (?) have been detected in one locality in Switzerland by Heer. The Australo-Indian forms give place to plants of an American type, resembling the existing vegetation of the United States, Mexico, and Japan. One of the most striking features is the abundance of Palmaceæ, together with Monopetalous Dicotyledons, especially a supposed Rubiaceous genus, *Steinhauera*. The list of fossils contains also a *Bambusa*, Lauraceæ, Combretaceæ, Leguminosæ, Apocynaceæ, belonging to warm climates, with many Amentaceous trees, Aceraceæ, Proteaceæ, and other plants now belonging to temperate regions. Numerous vegetable remains occur in beds of this formation at Bovey Tracey, Devonshire, and in the Isle of Wight.

### C. Pleiocene Flora.

966. The Dicotyledons predominate, and are most varied, as in existing vegetation; the Monocotyledons are rare; and the Palmaceæ of the preceding epochs are wanting. The general analogy of the flora is with those of the temperate regions of Europe, North America, and Japan at the present day. According to the determinations made by palæontologists, many existing genera are represented, such as *Taxodium*, *Salisburia*, Cyperaceæ, *Comptonia*, Thymelaceæ, Santalaceæ, *Liquidambar*, *Nyssa*, *Robinia*, *Gleditschia*, *Bauhinia*, *Cassia*, *Acacia*, *Rhus*, *Juglans*, *Ceanothus*, *Celastrus*, *Sapindus*, *Liriodendron*, *Capparis*, *Sideroxylon*, *Achras*, *Symplocos*, Cornaceæ, Myrtaceæ, Pomaceæ, Tiliaceæ, Magnoliaceæ, &c. This list includes especially modern North-American genera, which existed at that time in Europe (§ 954). *Quercus Acer* &c. appeared then as now.

### D. Pleistocene Deposits.

967. The glacial drift and the diluvial deposits belonging to this group afford hardly any recognizable vegetable remains, beyond fragments of fossil wood of Coniferæ, met with occasionally in connexion with the bones of extinct Mammalia, and in a few lignite beds.

The flora of the glacial period still exists in Alpine districts.

## 4. *Floras of Early Formations of the Present Geological Period.*

968. The formations referable to this group consist chiefly of freshwater calcareous deposits (tufa), the older peat-bogs, and forests now buried or submerged beneath the sea.

969. The remains existing in calcareous tufa have not yet been well investigated, partly because the beds are not greatly developed in most countries, and partly because they usually contain only casts of vegetable structure, produced through incrustation. As far as we know, the plants are similar to those of the existing floras of the regions, with a few exceptions.

970. The old peat-bogs, especially of Northern Europe, often contain vast quantities of recognizable vegetable remains, belonging to species no longer growing in the same spots, but found further south, as remains of *Corylus*, *Pinus Picea*, &c. in the Shetland Islands, of Oaks, Maples, Limes, Ash, &c. in Sweden, beyond the present limits of those plants.

971. Remains of forests formed of still existing species occur in many parts of Europe, enclosed in diluvial beds. The city of Breslau stands on the site of an ancient forest, whence the trunks of *Quercus pedunculata* are dug out; the same is the case with the city of

Bamberg, where the trunks of trees of great diameter have found in excavations for railways &c. Similar trunks of Oak occasionally dug out of the diluvial beds in England, as in the part of the valley of the Medway.

972. Submarine forests are known to exist off many poin the British coast and the west coast of France; wood obtained a large submerged bed off the coast of Pembrokeshire is foun consist of Oak and Alder, and the wood of *Pinus sylvestris*; Oak, Elm, Hazel, Walnut, &c. are found in the British Chann

These facts, together with the analogous but more complete dence derived from animal remains, show a gradual transition the Tertiary to the present geological epoch.

# INDEX TO SYSTEMATIC BOTANY,

CONTAINING THE

BOTANICAL NAMES OF CLASSES, ORDERS, AND GENERA, AND THE VERNACULAR NAMES OF SPECIES, REFERRED TO IN PART II. OF THIS WORK.

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